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SOVIET SOIL SCIENCE

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THE DECEMBER PLENUM OF THE CENTRAL COMMITTEE OF THE COMMUNIST PARTY OF THE SOVIET UNION

The Plenum of the Central Committee of the Communist Party of the Soviet Union ended its meeting December 25, 1959. The Plenum dealt with problems relating to the expansion of agriculture, increased production of grain, technical crops, vegetables, including potatoes, fruits, etc. Other topics of discussion were promotion of livestock raising, increased production of meat, milk, eggs, etc., reduction of costs, raising labor productivity, strengthening kolkhoz economy, providing kolkhozes and sovkhozes with more skilled workers, and improving the material welfare of farm workers.

The Plenum noted that urban and rural workers, inspired by the resolutions of the Twenty-first Congress held in 1959, had achieved great progress in promoting industry and agriculture. This is the basis of our confidence that the Seven Year Plan for developing the country's economy will be fulfilled ahead of time. A large-scale socialist competition has been organized among farm workers to fulfill the plan within four or five years. The Plenum was addressed by N. S. Khrushchev, agricultural leaders, heads of kolkhozes, milkers, machine operators, men and women pig tenders. They indicated that tremendous progress could be made in producing agricultural crops and in livestock raising if our resources were used skillfully and with initiative.

The Plenum also called attention to shortcomings that must be eliminated if agriculture is to advance, pointing out that its requirements must be thoroughly understood, since it is as complex as any other branch of our socialist economy.

The main shortcoming "is the great variety in level of economic activity in the kolkhozes and sovkhozes." Often kolkhozes and sovkhozes and entire districts adjacent to each other, and with the same natural conditions, have substantially different records of crop yield, livestock production, etc. "The experience of our leading kolkhozes and sovkhozes clearly indicates that the production of crops and livestock depends chiefly on skillful organization, maximum utilization of available resources, and wide employment of science and advanced technology."

The Plenum noted that sound agricultural practices were sometimes grossly violated: planting at the wrong time, poor use of fertilizers, delays in harvesting, systematic nonfulfillment of fallow and fall plowing schedules, etc. In several regions, the evidence shows, arable land ans sowing areas have been reduced (Vologod, Novogorod, Pskov Oblasts, Latvian, and Estonian SSR).

The Plenum called attention to shortcomings in the work of agricultural research organizations.

The resolution of the Plenum states that "the V. I. Lenin All-Union Academy of Agricultural Sciences, many research institutes and schools are not energetically solving the most important problems of theory and are too slowly reorganizing their work to relate it more closely to production. The work of scientific agencies is so organized that many scientists are not responsible for implementing their findings and recommendations."

The Plenum stressed the need of the various scientific institutions and experimental stations to strive to raise the level of agriculture and improve their service to kolkhozes and sovkhozes.

The resolutions of the Plenum outline various organizational measures designed to increase agricultural production. The most important is to devise methods whereby each district, kolkhoz, and sovkhoz can fulfill its part of the Seven Year Plan ahead of time and increase the output of crops and livestock. For this purpose it is highly important to find and mobilize all the available resources, use fertilizers efficiently, and cultivate the soil correctly and at the right time, etc.

According to the Plenum, "agricultural science is to develop theoretical research making maximum use of the latest achievements of biology, physics, chemistry, and allied disciplines to ensure increased productivity and continuing technological progress in agriculture."

The December Plenum thus showed that further advances in USSR agriculture will depend on improved organization of the kolkhozes and sovkhozes gaining deeper knowledge of the soil and its correct utilization, including efficient techniques of fertilization and cultivation.

This was particularly stressed by Comrade N. S. Khrushchev: "Having outstanding personnel, as we do, we must now proceed more widely as well as more deeply, increasing the areas under cultivation and the yield by the use of improved methods and achieving greater productivity of labor along with decreased costs. Our approach is not through extensive agricultural practices, which are based mostly on expanding the areas of cultivation, but through highly skilled intensive activity that results in obtaining the maximum amount of production from each hectare of land per unit of labor invested — that is our way."

Thus Soviet soil scientists and agricultural chemists are confronted with the vast task of devising methods of fertilizing, cultivating, and improving the soils differentiated by zones. We must accelerate the mapping and site classification soils in kolkhozes and sovkhozes and working out scientific ways to increase soil fertility in the USSR.

FRACTIONATION OF ISOTOPE OXYGEN IN THE SOIL

L. M. KHITROV and I. K. ZADOROZHNYY, V. I. Vernadskiy Institute of Geochemistry and Analytical Chemistry, Academy of Sciences, USSR

Atmospheric oxygen is known to consist of the stable isotopes O^{16}, O^{18}, and O^{17} found in the ratio of 500:1:0.2, or as percentages of occurrence in the atmosphere (constant at various points and altitudes):

O^{16} - 99.759%; O^{17} - 0.0374%; O^{18} - 0.2039% (22).

The atmosphere contains approximately 1 x 10^{15} metric tons of oxygen. As a result of continuous photosynthesis, this oxygen is renewed every few thousand years (3).

It seemed worthwhile to study the migration of such large quantities of matter as well as the possible fractionation of the previously mentioned isotopes during the biological and physicochemical processes taking place in nature. It is evident from the isotopic composition of atmospheric oxygen that fractionation occurs naturally. This oxygen is produced from oxygen in the water during photosynthesis (2). If we take the density of the standard oxygen of river water as unity, the density of atmospheric oxygen is 3.22% higher as a result from enrichment of the latter with isotope O^{18} (17). One of the main reasons for this phenomenon is apparently the different rate of the chemical reactions of oxygen isotopes during oxidation, combustion, and respiration in nature wherein isotope O^{16} is absorbed more rapidly owing to its great energy potential.

The enrichment of oxygen during respiration has been found in a number of biological objects (21) and in the isotopic composition of oxygen dissolved in sea water (23). Similar fractionation was recently demonstrated in the waters of the Indian Ocean. Here the isotopic enrichment resulted from the processes of both respiration and oxidation of detritus (5).

It can now be considered an established fact that the processes of absorption of atmospheric oxygen taking place in the ocean enrich the oxygen with isotope O^{18}. This is the main but not the only source of oxygen enrichment. The soil is obviously another such source.

The role of the soil in the distribution of oxygen on the earth is quite substantial. Let us try to evaluate it roughly. Following Rommel's hypothesis (24) that the air in the top 20 cm layer is completely renewed every hour and taking the useful area of the soil (without glaciers, snow, and deserts) as 124 million km² (10), we obtain 1.7 x 10^{11} metric tons of oxygen passing through the top layer of soil daily. On the other hand, if we use the figure of 1.3 x 10^{11} metric tons of carbon dioxide produced annually by the soil (13), we come up with 1.0 x 10^{11} metric tons of oxygen required. Despite the possibile discrepancies inevitable in such rough calculations, it is evident that a substantial portion of the 2.7 x 10^{11} metric tons of oxygen produced annually during photosynthesis is used up in the soil. The soil is second only to the ocean in this respect. Thus, about 5 x 10^{8} metric tons of "heavy" oxygen pass annually through the soil in addition to the light isotope O^{16}. No reports have as yet been published on the isotopic composition of oxygen in soil air. An investigation was made of the isotopic composition of oxygen in atmospheric carbon dioxide (20). Changes in isotopic composition (depending on meteorological conditions and time of the day) ranged from +0.29 to -0.19% sample of CO_2.

The available material on the fractionation of oxygen during the respiration of soil bacteria in experiments in vitro (18) cannot be regarded as wholly reliable owing to insufficient rigor in setting up the experiments.

The isotopic composition of soil air can be determined from several processes.

The processes of air exchange and gas exchange are distinguished in connection with the migration of air in the soil (9). With air exchange caused by changes in temperature, barometric pressure, blowing of soil air by the wind and displacement by moisture, there is no change in the concentration of the constituents of the air entering and leaving the soil. With gas exchange, the chemical composition of the incoming and outgoing air is changed by diffusion, soil respiration, and the processes of sorption-desorption of gases, i. e., the processes capable, in principle, of causing isotopic fractionation. It is obvious that gas exchange and air exchange do not take place in nature independently of one another.

The diffusion of gases is a major factor in atmosphere-soil exchange (14). There is also some evidence for believing that the sorption-desorption processes of gases may well exert considerable influence on soil structures (12).

It is worth noting here that isotopic fractionation has been discovered in nitrogen gas passing through porous sandstone by effusion and superficial diffusion (19). However, the most important factor in gas exchange is soil "respiration," i. e., the intake of oxygen and discharge of carbon dioxide through the respiration of microflora and roots and the oxidation of the organic components of the soil. The rate of soil respiration varies directly with the season, temperature, soil moisture and structure, amount of microorganisms and roots, and, finally, with the stage of development reached by plants on a particular soil (7).

The present paper is an investigation of the isotopic composition of oxygen in the air of several groups of soil taken from various depths at different times in order to determine the possibility of fractionation.

Procedure

Samples of soil air were obtained from different depths by means of two systems of samplers (15, 8). A heavier auger of the second type was used to obtain samples from depths above 40 cm or from soils containing a large quantity of solid inclusions.

A check revealed that the data on chemical analysis of the air taken from a depth of 35 cm by samplers of both types (at a distance of 80-100 cm) completely coincide. The possibility of drawing in atmospheric air through the space between the sides of the auger and the soil was eliminated by sealing the space with plasticine (16). The failure of atmospheric air to be drawn in as well as the low air permeability of the particular soils are shown by the fact that a vacuum of 41-mm mercury column, created by pumping out air from the sampler sunk to a depth of 40 cm in moist fine clay loam, did not change perceptibly for 40 minutes. The soil air was obtained by two methods — one involving the use of a salt solution (suction fluid), the other involving evacuated ampoules. A 350-500-cm³ Zeger gas pipette was employed with the former. For the sake of economy the salt solution was removed from the receiving pipette into another, evacuated pipette. This enabled us to use 600-650 cm³ of the solution for 25-30 samples. Before obtaining a sample we washed the inside of the sampler and feed pipes with the soil air of the given horizon. Then, depending on the arrangement of the auger, 200 cm³ of soil air was admitted to the receiving pipette after which a three-way stopcock was opened to "air" and the wash air discarded by raising another pipette that served as a special pump. The stopcock was then turned to "soil" and the sample taken. Without this washing the difference in chemical composition between the first and succeeding portions of air amounted to 6%-10%. This procedure enabled us to obtain samples uncontaminated by atmospheric air with a minimum consumption of salt solution.

The other method of obtaining samples involved the use of evacuated Zeger pipettes. They were evacuated to 1-2-mm mercury column with a rough exhaust pump in the laboratory. One of the pipettes was used to flush the system for which the pipette was connected to the sampler, and soil air collected there until the pressure in the pipette rose to 100-150-mm mercury column. The pipette was then disconnected and the sample drawn into the other evacuated pipette. A membrane vacuum gauge (GOST 1011-53) served to control the degree of exhaustion of the pipette and the rate at which the sample was obtained. A single sampling took 2-3 minutes. The evacuated pipette was washed with nitrogen once or twice for greater cleanness.

This method is very convenient, particularly in the winter. It requires a rough exhaust pump, pipettes with well-ground stop cocks (vacuum grease applied), and appropriate means of moving the ampoules to prevent the vacuum from being disturbed.

The chemical composition of soil air taken from a single point by the two methods used one after the other was completely identical.

An apparatus based on the GKh-I gas analyzer was used for chemical analysis of the air for oxygen and carbon dioxide. A gas burette of a previously described type and zero manometer with oleic acid were mounted on it (11).

One of the principal sources of error in gas analysis is the trickling of liquid down the sides of the gas burette when readings are taken. Burette with paraffin sides is a clumsy and inadequate way of obtaining nonwettable sides. Instead, the sides were coated with a silicone. After the fat was carefully washed off, the gas burette was dried in the air and filled two or three times with a solution of methyl trichlorosilane in carbon tetrachloride (1-2 drops of the silicone to 5 ml of CCl_4). After the solution (reusable) was poured off, the burette was dried at 100-105°C. The result was that the walls had an unwettable surface with a film several tens of molecules thick, which, of course, has no effect on the capacity of the burette. The surface of the barrier liquid in the burette becomes completely level. The film is resistant to neutral solutions and is destroyed only by strong liquids, particularly alkali.

The gas analyzer setup also contained a four-way stopcock. In the first position, the feed tube is washed with air to be analyzed; in the second position, the burette is filled with air; in the third position, the analysis is made and the gas expelled from the burette in connection with its preparation for the following determination. This sequence of operations makes it possible to exclude the natural volume of the connecting strip because it is completely filled with the nitrogen remaining after the alternate determination.

The sensitivity of the apparatus was 0.015%. A temperature correction found experimentally must be introduced in order to obtain agreeable results in parallel analyses.

The samples were prepared for isotopic analysis on the apparatus shown in Figure 1. The evacuated system was washed with nitrogen after which gas from the pipette (the open lower stopcock of which was immersed in a salt solution) passed into the connecting strip

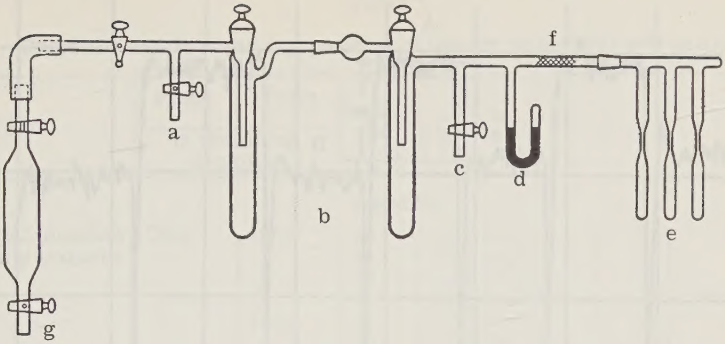

Fig. 1 - Apparatus for the preparation of samples of soil air for isotopic analysis by the mass spectrometer.

a - stopcock for washing the system with nitrogen; b - trap-driers c - vacuum stopcock; d - manometer; e - ampoules for samples; f - filter of sterile cotton; g - lower stopcock of pipette immersed in salt solution.

with the ampoules, each of which was 6-8 cm³ in capacity. The open system permitted the ampoules to fill up completely with the gas. We observed no changes in the isotopic composition resulting from the sample's contact with the salt solution. The gas was freed from moisture as it passed through a drier immersed in a cooling mixture (dry ice with acetone).

To prevent changes in the isotopic composition of the samples during storage owing to the respiration of the microbes found on the sides of the ampoules, the latter were first sterilized at 150°C while the gas therein passed through sterile cotton. A cotton filter was also inserted in the feed tube when the air was taken from the soil.

The isotopic composition of the oxygen was measured with an MS-2 split-beam mass spectrometer. With the absolute method ionic-rays of all the isotopic masses to be compared are directed into the slit of the ion receiver and their intensity measured. This method makes it possible to determine variations in isotopic composition with an accuracy of ± 0.3-0.5%. To study variations in the isotopic composition of oxygen in natural objects requires an increase of accuracy to 0.02-0.05%. Accordingly, measurements are made by the compensation method, which consists essentially of the following. A double ion receiver accepts simultaneously two ionic beams with a mass of 34 and 32 corresponding to the isotopic molecules $O^{16}O^{18}$ and $O^{16}O^{16}$, which after being intensified enter a compensator where the values of the flow rate from each beam are compared (4). The result of the comparison, which shows the ratio of $O^{16}O^{18}:O^{16}O^{16}$, is recorded on the chart of an EPP-09 automatic potentiometer.

To increase accuracy even further, a sample and a standard are placed in the ion source of the mass spectrometer at 2-3-minute intervals and the corresponding recording made (Fig. 2). The value of the parallel displacement of the sections of the recording is proportional to the difference in the isotopic ratios of both gases.

The distance measured on the chart and the values of the isotopic ratios are interrelated as follows:

$$\delta = \frac{\left(\frac{O^{16}O^{18}}{O^{16}O^{16}}\right) \text{ of the sample} - \left(\frac{O^{16}O^{18}}{O^{16}O^{16}}\right) \text{ of the standard}}{\left(\frac{O^{16}O^{18}}{O^{16}O^{16}}\right) \text{ of the standard}} \text{X } 100,$$

where δ is the difference expressed as a percentage.

The gases were admitted alternately through a two-chennel glass system, the standard is one channel, the sample in the other. From the channels the gases entered the mass spectrometer through a diaphragm about 0.05 mm in diameter and a set of valves.

We used as the standard atmospheric oxygen obtained beyond city limits. The error in measuring the isotopic ratio amounted to 0.03-0.05%

Results

Four groups of soils were investigated: podzolic (near Moscow), chernozem (Dnepropetrovsk, Kharkov, Kursk, and Voronezh Oblasts), humus-illuvial forest-tundra (Kolsk Peninsula), and red earths.

Podzolic soils. The most complete set of observations of soil air composition was made on the soils belonging to the Main Botanical Garden of the Academy of Sciences USSR (GBS AN). The different species of podzolic soils were determined from the GBS soil map (1).

Samples of soil air from weakly podzolic, sandy loams underlain with sand were obtained systematically at different times of the year. The source was a small clearing that had not been cultivated for a long time and is now planted to Thuja. Samples were obtained in

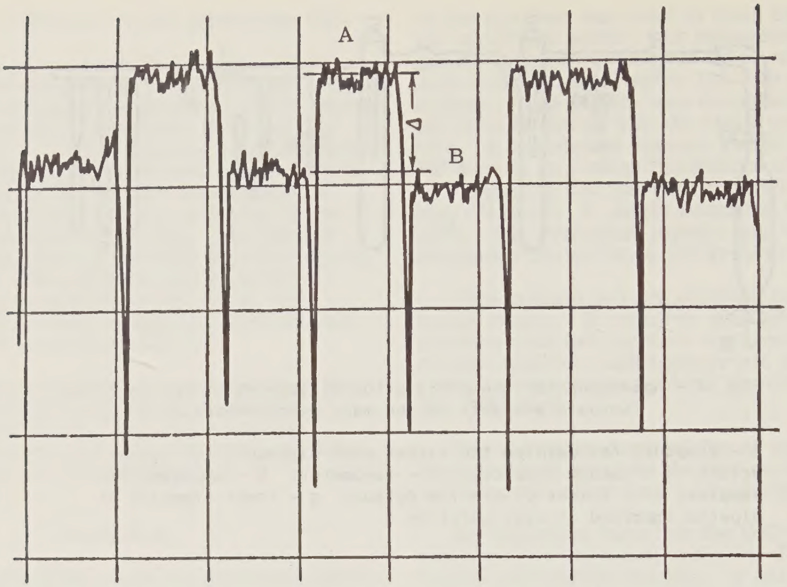

Fig. 2. - Example of recording of isotopic ratios on potentiometer chart.

A - ratio $\frac{O^{16}O^{18}}{O^{16}O^{16}}$ of the sample; B - ratio $\frac{O^{16}O^{18}}{O^{16}O^{16}}$ of the standard;

Δ - difference in isotopic ratios.

the summer from alluvial-meadow weakly podzolic soils in the Likhoborka River flood plain. Individual samples were also obtained from strongly podzolic clay loams (Betuletum herobsum section of the forest).

Chernozems. Samples were obtained in September 1958 from the following districts: leached chernozem, of great thickness, on the grounds of the experimental station of the Voronezh Agricultural Institute. This chernozem was developed on clay loam whose depth of effervescence was 75-105 cm; the humus content through the horizons ranges from 7.7% to 2.7%. Thickness of horizons $A_1 + A_2$ is 50-72 cm, A_1B_1 greater than 75 cm. The samples were obtained near a corn field in an unplowed section.

A typical thick chernozem, fine clay loam on loess-like clay loam, came from Gubkin rayon, Kurskaya oblast'. The samples came from an abandoned area largely covered with Achillea millefolium and Odontites. A leached fine clay loam came from Liski rayon, Khar'kovskaya oblast'. The samples were taken from an abandoned area near a sugar-beet field.

Forest-tundra soils. Samples were taken from gley-humus-illuvial soils in the sparse forest-tundra region in Lovozer rayon on Kol'sk Peninsula in August 1958. Soil air was obtained from a depth of 25 cm in a clearing amidst a sparse birch stand near the lake. Excessive moisture, high level of soil water, and abundance of boulders (in horizon A_2 and particularly horizon B) made it impossible to obtain air from a greater depth. The air was obtained from the foregoing point for 28 hours, i. e., the daily variations in composition were checked simultaneously. We also obtained samples from another plane — a small meadow, at a depth of 30 cm, in Motka rayon.

Red earths. Samples were obtained in Chakvi rayon 5 km from the sea from a very hilly area in October 1958 several days after it had rained.

The samples were generally obtained from depths of 20, 40, 60, 85, and 100 cm, usually at about the same time in the afternoon. The results were presented in Table 1 where the isotope enrichment δ computed from the formula given previously is hown along with the data of the chemical analysis of the soil air. The fractionation coefficient $(\alpha = 1 + \delta \times [100])$ and O^{18} content in soil air as a % computed from α are also shown in cases where isotopic fractionation took place. To find the latter values, the O^{18} content in the standard atmospheric air was taken as equal to 0.2039%. Moreover, α in our case need not necessarily designate the thermodynamic equilibrium achieved between the isotopic composition of soil and atmospheric oxygen.

The fractionation of oxygen isotopes, as is evident from Table 1, is rather slight and not constant. It is not associated with an increase of carbon dioxide in soil air and decrease of oxygen, which is an indicator of the level of the biological processes in the soil. For example, the maximum carbon dioxide content of

Table 1

Chemical and isotopic composition of the air in several soil groups

Soil	Place	Time	Depth cm	CO_2 in %	O_2 in %	δ	α	% content of O^{18}
	of obtaining samples							
Podzolic								
Alluvial-meadow weakly podzolic	GBS	June	20	0,50	20,21	0	None	
			40	1,36	19,76	0	"	
			60	2,02	19,65	0	"	
			80	1,68	19,75	+0,04±0,02	1,0004	0,2039
	"	July	20	0,93	19,84	0	None	
			50	2,47	18,01	0	"	
			70	2,82	17,82	0	"	
			90	2,73	17,45	0	"	
		January	40	0,35	20,40	0	"	
Weakly podzolic, sandy clay underlain with sand	GBS	June	20	1,32	19,40	+0,10±0,02	1,0010	0,2041
			50	1,68	19,20	+0,10±0,03	1,0010	0,2041
"	"	July	20	2,37	18,35	Not det'd.	Not det'd.	
			40	2,20	19,30	0	None	
			60	2,58	18,76	0	"	
			85	2,16	18,29	0	"	
"	"	October	20	1,13	19,81	Not det'd.	Not det'd.	
			40	1,22	18,80	0	None	
				1,12	19,34	0	"	
"	"	November	20	0,57	20,42	Not det'd.		
			45	0,88	20,01	"		
			70	1,11	19,33	"		
"	"	May	25	3,72	16,42	0,06	1,0006	0,2040
Strongly podzolic clay loam	GBS	Dec.	40	0,45	19,58	0	None	
	"	July	40	3,68	16,42	+0,11±0,03	1,0011	0,2041
		"	20	C,34	20,30	+0,05±0,02	1,0005	0,2040
Chernozem								
Ordinary medium- and slightly humus medium-thick	Terney, Dnepropetrovsk Oblast'	Sept.	20	0,10	20,60		Not det'd.	
			85	0,80	20,30	0	None	
			40	0,66	19,95	0	"	
			70	0,91	18,30	0	"	
			20	0,07	20,12	0	"	
			70	0,64	19,70	0	"	
			100	0,83	19,55	0	"	
Ordinary medium- and slightly humus thick	Dnepropetrovsk Oblast'	"	20	0,76	20,11	Not det'd.		
			40	0,67	20,30	0	None	
			60	0,72	19,86	0	"	
			85	0,72	19,86	0	"	
Leached medium humus thick	Khar'kov Oblast'	"	20	0,14	20,07	0	"	
			40	0,31	20,29	Not det'd.		
			60	0,60	20,16	0	None	
			85	Not det'd	20,20	Not det'd.		
Northern medium humus, extra thick	Kursk Oblast'	"	20	0,42	20,04	0	None	
			50	0,68	20,11	0	"	
Leached of increased thickness	Voronezh Oblast'	"	20	0,42	20,19	Not det'd.		
			40	0,68	20,03	0	None	
			60	0,76	19,92	0	"	
			85	1,11	19,80	0	"	
			90	0,22	20,45	0	"	
Forest-tundra								
Gley-humus-illuvial (sparse forest tundra)	Kol'sk Peninsula	August	20	2,50	17,60	+0,13±0,03	1,0013	0,2041
			20	2,00	18,30	+0,12±0,03	1,0012	0,2041
			20	2,31	17,90	+0,11±0,04	1,0011	0,2041
			20	1,29	18,91	+0,11±0,04	1,0011	0,2041
			20	1,38	19,00	+0,11±0,03	1,0011	0,2041
"	"	July	20	1,35	18,35	+0,10±0,03	1,0010	0,2041
Red earths								
Red earth	Chakvi	October	20	0,46	20,05	0	None	
			45	1,18	19,50	0	"	

Note: Comma represents decimal point.

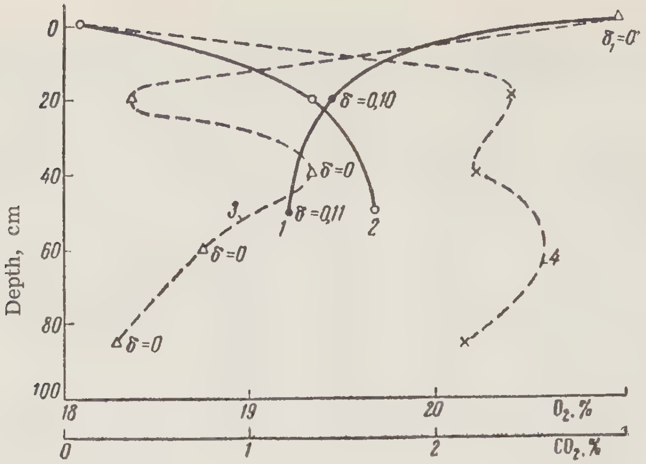

Fig. 3. - Composition of soil air and its isotopic enrichment (δ) in podzolic soil.

Samples obtained in July 1958 (soil water at 55-60 cm level). 1 - oxygen content; 2 - carbon dioxide. Samples obtained in July 1958 (soil water below 85 cm); 3 - oxygen content; 4 - carbon dioxide.

podzolic soils was observed in July, when it approached 3%. It is precisely at this time that the most intense respiration of the soil occurs (7). However, this had no effect on the isotopic composition of the oxygen. Furthermore, isotopic fractionation took place when the carbon dioxide content was much lower. But this was invariably due to considerable amounts of moisture in the soil. For example, air samples from weakly podzolic, sandy loam soils in July when the level of soil water was below 90 cm did not reveal fractionation, whereas samples taken from the same place in June after heavy rains revealed enrichment with heavy oxygen (Fig. 3). Hence the soil water was at the 55-60-cm level, and it was impossible to obtain air from greater depths. Fractionation was also noted on strongly podzolic, clay loam soils where high moisture content prevented us from obtaining air in the deep horizons.

Samples were taken from chernozems at the end of the growing period during a dry and warm fall. Despite their high humus content the amount of carbon dioxide in the soil air was comparatively slight. No changes were noted in the isotopic composition.

Fractionation was observed in all the samples of soil air from the forest tundra of the Lovozerskiy massif where the water content of the low-lying and partially swampy areas was very high. The soil water level was at the 25-30 cm mark.

As mentioned previously, we checked here on changes in the composition of the soil air during the course of a day. Figure 4 shows that the highest point of biological activity occurs at 1800 hours. Changes in air composition at different times of the day have no perceptible effect on the isotopic composition of the oxygen.

Thus, observations of fractionation are linked not so much to the level of biological activity in the soil as to the presence of large amounts of moisture. Fractionation may be caused by physicochemical as well as biological processes.

Oxygen Fractionation in the Presence of Ferrous Iron

Fractionation may be caused by the oxidation of inorganic components of the soil, e. g., iron. The relationship between the fractionation of isotopes and the presence of nonoxidized products in the soil is illustrated by the following.

We obtained samples of soil air from the limonite layer in soil from the flood plain of the Vorya River, Moskovskaya Oblast' in July 1958. We began to come across iron concretions containing ferrous iron (1.40% FeO) at a depth of 15-20 cm in red-brown, very coarse-textured soil; the number of these concretions was greatest at 40-50 cm (with ferrous iron content of 2.47% FeO). These concretions were found at a greater depth virtually in decomposed condition. The chemical composition of the air in relation to depth in these soils is shown in Table 2.

The table shows that the 40 cm depth where most of the ferrous iron is found contains the least amount of oxygen in the soil air. Since the corresponding maximum of carbon dioxide content was not found in this horizon, we assume that the oxygen deficiency here is caused by its being consumed in oxidation of the iron of the concretions. Yet here too there was no isotopic fractionation. Nor was there any fractionation in samples taken from red earths. It is interesting to note that several reports (6) mention that oxidation of iron compounds uses oxygen

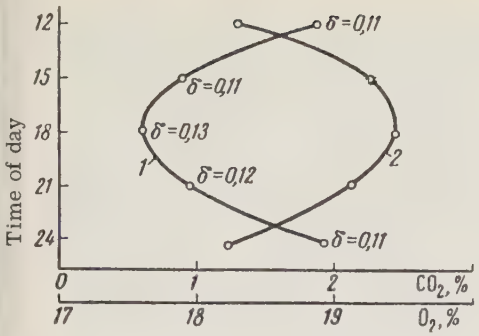

Fig. 4. - Daily variations in the composition of soil air in forest tundra (20 cm deep).

1 - oxygen content; 2 - carbon dioxide; δ - isotopic enrichment.

Table 2

Chemical and isotopic composition of the air from soils with a limonite layer, Moskovskaya Oblast', Vorya River

Depth, cm	CO_2	O_2	FeO	Isotopic fractionation
	as a %			
20	0,31	20,75	1,40	Not det'd.
40	0,45	20,10	2,47	0
60	0,56	20,51	1,82	0
85	0,58	20,80	Not det'd.	0
110	0,66	20,09		0

mainly from water rather than from air. This observation is contradicted in the foregoing case by the absence of fractionation in the oxidizing zone.

Conclusions

1. An investigation of the isotopic composition of oxygen in the soil air of different groups of soils has shown that in some cases isotopic fractionation of oxygen tends toward enrichment with isotope O^{18}. This enrichment is comparatively slight. The fractionation coefficient varies from 1.0004 to 1.0013.

2. In view of this insignificant fractionation (in the samples studied) it is believed that the soil exerts little influence on the general enrichment of atmospheric oxygen during gas exchange between the atmosphere and the soil.

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CHARACTERISTICS OF SOIL STRUCTURE IN FLOOD-PLAIN OAK STANDS

G. V. DOBROVOL'SKIY and N. F. TITKOVA, Moscow State University

> "Earthworms have played a much more important role in the history of the formation of the earth's crust than might seem possible at first glance."
>
> C. Darwin

Most flood-plain soils have a granular structure. Granularity is so characteristic of many varieties of flood-plain soils that it serves as a basis of classification and nomenclature (3, 17). It is well known that the granular structure of these soils resulted not only from the properties of the alluvium but also from the effect of the rich grassy vegetation of water meadows on this alluvium. We find in flood plains not only meadows, but also forests. Forest vegetation, in the opinion of most investigators, is primary here. What is the soil structure in water meadows, its genesis and properties? Very little has been published on the problem.

While working in the flood plain of the middle and lower reaches of the Klyaz'ma River where substantial forest areas have survived, we become interested in the problem and made special observations to elucidate the characteristics of soil structure in the flood-plain oak stand. These observations were conducted on the territory of the former Klyaz'ma forest reservation between the villages of Knyaginkino (Kovrovskiy rayon, Vladimirskaya oblast') and Naberezhnaya (Savvinovskiy rayon, Ivanovskaya oblast'). The flood plain in this district is 3-5 km wide and clearly differentiated into three genetic zones — river bed, central, and pre-terrace. The relief is ridgelike in the river-bed zone and characterized by sloping ridges in the central zone. The vegetation is represented by flood meadows and forests. Mixed grass associations are predominant in the meadows and, partially, in the central zone, while the forests are represented by light oak stands (16, 9).

The soil is highly varied. Sod and sod-meadow soils predominate in the river-bed and central zones, whereas meadow-bog and bog (including alder) soils predominate in the pre-terrace zone (8).

The very first field observations showed that the soil structure of flood-plain forest differs markedly from that of analogous types of soils under grass. To make a careful study of the matter, we selected soils that were most alike in stage of formation (nature of the alluvium, level of ground water, element of relief) — in one case under oak, in the other under meadow vegetation.

Soil samples for laboratory analysis were taken from four profiles. The first pair of profiles was on a comparatively high ridge of the flood plain near the river bed, one under oak (sod-forest soil, profile 2), the other on the same ridge under a mixed-grass meadow (sod soils, profile 1). The second pair of profiles was on a lower and more sloping ridge on the central flood plain, one under oak (sod-meadow-forest soil, profile 4), the other under a mixed-grass meadow (sod-meadow soil, profile 3). The names of the soils follow the classification suggested by Dobrovol'skiy (6).

The soils and vegetation of the high ridge near the river bed (profiles 1 and 2) have no contact with ground water (except during floods), while the soils and vegetation of the sloping ridge briefly and periodically obtain moisture from ground water by capillary action, as is evident from the data presented in Table 1.

Herewith is a brief description of the soil profiles found on the ridge of the flood plain near the river bed:

Flood-plain sod clay loam. Profile 1

Crest of low ridge near the river bed. Fescue-mixed grass meadow. Ground water about 3 m deep. July 1956.

A 0-3 cm. Dark brown, slightly compact earthy sod. Sod of fine earths — medium clay loam. Coprolites found.

A_1 3-17 cm. Gray-brown, granular-powdery, coarse clay loam, slightly compact. Penetrated by grass roots. Many earthworms, coprolites, and channels.

B_1 17-40 cm. Brown, blocky-powdery, sandy loam, slightly compact, many grass roots; earthworms and coprolites found.

C 40-100 cm. Light brown loose, struc-

Table 1

Field moisture of soils as a %, July 1957

Depth, cm	Profile 1. Sod	Profile 2. Sod-forest	Profile 3. Sod-mead.	Profile 4. Sod-meadow-forest
0	21,00	23,00	31,40	31,38
10	15,42	17,02	35,87	32,42
20	10,61	10,48	35,80	23,02
30	6,87	11,91	22,64	14,08
40	6,43	9,52	16,38	9,62
60	6,90	7,17	11,50	6,63
80	6,84	4,07	12,03	7,55
100	3,68	4,50	12,32	15,32
120	3,87	3,99	16,95	16,11
140	6,33	3,44	19,41	19,08
160	5,03	3,33	20,38	23,01

Note: Comma represents decimal point.

tureless sand.

Flood-plain sod-forest clay loam. Profile 2.

Crest of the same low ridge near the river bed. Oak stand with undergrowth of bird cherry, mountain ash. Sparse herbage of meadow and forest forms.

A_0 0-1 cm. Loose oak litter.

A_1' 1-7 cm. Brownish-gray, friable-granular, clay loam, loose; delicate woody roots predominate; intertwined with thick fungal mold; granular structure consists almost entirely of worm coprolites.

A_1'' 7-19 cm. Grayish-brown, granular-powdery, clay loam. Roots are fewer but larger. Much fewer but larger. Much fewer worm coprolites.

B_1 19-37 cm. Brown, sandy loam, loose, sparse woody roots.

C 37-100 cm. Light brown, structureless, loose sand.

It is evident from the foregoing that the soil under forest differs markedly from the soil under meadow primarily in structure and nature of the humus-accumulative horizon. In the soil under meadow the sod gradually changes into a comparatively uniform humus horizon with granular-powdery structure and intertwined with grass roots. The forest soil has no sod, but the humus-accumulative horizon is divided into two subhorizons of which the upper one (A_1') lying directly under the forest litter has a highly unusual friable-granular structure.

Structural analysis according to Savvinov likewise showed a substantial difference between the structure of the soils in flood-plain oak stands and that of the soils under flood-plain meadows. Figure 1 clearly reveals that the upper horizons of the forest soils have an exceptionally high structural state, with most aggregates measuring 3-5 cm in diameter, while the dispersed portion (<0.25 mm in diameter) amounts to about 5%. The soil structure of flood-plain oak stands also has a high degree of water stability (Table 2).

The quantity of water-stable aggregates in the sod-forest soil is almost double (77%) the quantity in sod soil (42%). And there are many more water-stable aggregates in the sod-meadow-forest soil (83%) than in the sod-meadow soil (64%).

What are the reasons for the highly structured condition of the humus-accumulative horizon of forest soils? Table 3 presents data of certain chemical properties of soils. They show that the flood-plain soils both under forest and under meadow vegetation, possess an acid reaction and that they do not differ in any important respect. It is true that forest soils contain somewhat more exchangeable calcium and humus than the analogous horizons under meadow vegetation, but it must be borne in mind that in forest soils the humus content is already considerably less at a depth of 8-10 cm, whereas in meadow soils the decrease with depth is much more even.

A comparison of particle size analysis (Table 4) showed that the upper horizons under forest have a similar but somewhat finer texture than the meadow soils. As for the sod and sod-forest soils, the difference in clay fraction content amounts to 2.5%.

The differences between the flood-plain soils under forest and under grass with respect to humus content, adsorbed bases, and texture may be partially responsible for the difference in structural condition of these soils. However, we do not consider them important enough to account completely for the extensive structural differences between the two soils.

Since plant roots, particularly the fine ones, play a major part in formation of soil structure we measured the root masses (roots less than a millimeter in diameter) in the soils. The results (Table 5) show that the amount of fine roots in the upper horizons under forest is much less than in soils under grass meadow. Consequently, factors other than the root system of plants must be responsible for the highly structured quality of the flood-plain forest soils. This led us to continue our research using optical and colloid chemical methods.

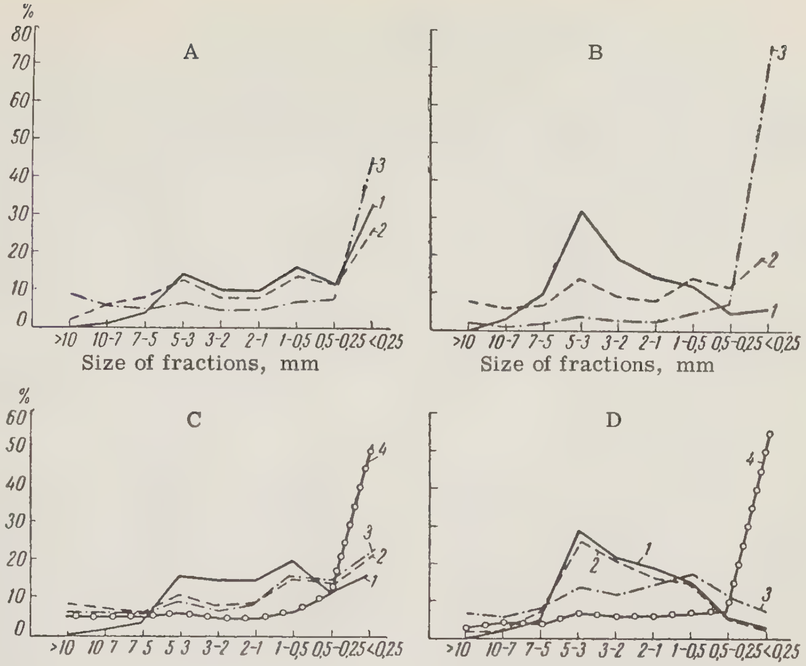

Fig. 1. - Structural condition of soils according to Savvinov (dry sieving).

A - sod soil. Profile 1. 1 - Ad 0-3 cm; 2 - A_1 5-15 cm; 3 - B_1 17-27 cm. B - sod-forest soil. Profile 2. 1 - A_1' 1-7 cm; 2 - A_1'' 8-18 cm; 3 - B_1 21-31 cm; C - sod-meadow soil. Profile 3. 1 - Ad 0-6 cm; 2 - A_1' 6-16 cm; 3 - A_2'' 21-31 cm; 4 - B_1 40-50 cm. D - sod-meadow-forest soil. Profile 4. 1 - A_1' 1-18 cm; 2 - A_1'' 8-18 cm; 3 - A''' 21-31 cm; 4 - B_1 40-50 cm.

Table 2

Water stability of aggregates as a % according to Savvinov

Profile No.	Soil	Horizon and depth, cm	Diameter of fractions, mm						
			>5	5—3	3—2	2—1	1—0,5	0,5—0,25	<0,25
1	Sod	A_g 0—3	5,86	9,13	5,97	12,36	6,11	3,15	58,42
		A_1 5—15	8,53	5,51	3,42	10,78	13,66	2,75	55,35
		B_1 17—27	0,38	0,46	0,39	0,66	3,90	6,80	87,40
2	Sod-forest	A_1 1—7	20,98	30,74	6,89	11,59	5,72	1,28	22,80
		A_1 8—18	7,86	8,15	5,18	8,89	26,15	6,23	37,54
		B 21—31	0,39	0,62	0,51	0,73	1,66	1,35	94,74
3	Sod-meadow	A_g 0—6	5,06	28,52	6,93	17,07	5,17	1,46	35,79
		A_1 6—16	3,73	4,08	2,66	7,28	13,65	2,87	66,73
		A_1 21—31	—	1,85	2,28	4,96	22,99	4,82	63,11
		B 40—50	—	0,95	1,14	2,01	2,09	3,82	90,00
4	Sod-meadow-forest	A_1 1—8	10,96	47,74	10,25	11,10	2,50	0,45	17,00
		A_1 8—18	12,81	44,72	9,55	20,07	2,89	1,16	8,80
		A_1 20—30	4,35	7,73	12,00	27,73	6,63	1,89	40,49
		B 40—50	0,63	1,16	1,52	3,73	8,36	4,87	81,53

Note: Comma represents decimal point.

Table 3

Chemical properties of soils

Profile No.	Soil	Horizon and depth, cm	Humus as a %	Exchangeable Ca in meq per 100 g of soil	pH	
					H_2O	KCl
1	Sod	A_g 0—3	5,88	17,91	5,7	4,7
		A_1 5—15	3,38	14,56	5,6	4,7
		B_1 17—27	—	—	4,9	4,1
		B_2 29—39	—	—	4,9	4,2
		C 50—60	—	—	5,0	4,3
2	Sod-forest	A_1 1—7	7,87	25,10	5,4	4,6
		A_1 8—18	2,55	18,23	5,2	4,4
		B 21—31	—	—	4,8	3,9
		C 50—60	—	—	5,1	
3	Sod-meadow	A_g 0—6	7,05	20,53	5,0	4,9
		A_1 6—16	5,02	16,34	5,5	4,8
		A_1 21—31	4,17	16,38	5,2	4,6
		B 40—50	—	—	5,0	4,1
		C 80—90	—	—	5,7	4,6
4	Sod-meadow-forest	A_1 1—8	11,40	28,96	5,6	4,8
		A_1 8—18	4,38	21,52	5,3	4,5
		A_1 20—30	3,93	23,53	5,2	4,2
		B 40—50	—	—	4,9	4,1
		C 80—90	—	—	5,1	4,6

Note: Comma represents decimal point.

Table 4

Particle-size analysis of soils as a % of dry soil weight

Soil	Profile No.	Horizon	Depth, cm	Fractions, mm						
				1—0,25	0,25—0,05	0,5—0,01	0,01—0,005	0,005—0,001	<0,001	Total of fractions <0,01
Sod	1	A_g	0—3	1,43	53,63	8,22	3,78	8,42	24,52	36,72
Sod-forest	2	A_1'	1—7	1,98	39,12	12,51	4,58	14,80	27,01	46,39
Sod-meadow	3	A_g	0—6	2,84	33,94	15,98	7,42	15,09	24,73	47,24
Sod-meadow-forest	4	A_1'	1—8	5,54	13,53	21,77	0,50	19,33	38,33	58,16

Note: Comma represents decimal point.

Examination of samples under a binocular microscope revealed that the soil mass of the humus-accumulative horizon of forest soils consists almost entirely of granular aggregates in which the coprolites of earthworms are predominant — round and angular grains with a smooth, even surface as though smeared with some sticky substance. Capillary saturation of these aggregates with water (from drops of water on the watch glass) takes place rather slowly, and water appears on the surface of the aggregate in the form of "condensate." Most of these aggregates do not disintegrate after total saturation, i. e., they are water stable. The high degree of water stability of coprolitic aggregates was noted a long time ago. This was confirmed during the past few years by a series of special studies (13, 14, 2, 10).

The humus-accumulative horizon of flood-

Table 5

Weight of roots (diameter < 1 mm) per area 25 X 25 cm

Profile No.	Soil	Depth, cm	Weight of roots, g	Profile No.	Soil	Depth, cm	Weight of roots, g
1	Sod	0—5	36,4	3	Sod-meadow	0—5	44,1
		5—20	13,6			5—20	18,5
		20—40	5—2			20—40	6,1
2	Sod-forest	0—5	18,4	4	Sod-meadow-forest	0—5	22,3
		5—20	16,2			5—20	22,5
		20—40	5,3			20—40	14,8

Note: Comma represents decimal point.

plain soils under grass meadow is a powdery-granular mass. Among the granular aggregates predominate grains of the most varied form with rough, uneven surface on which individual particles of sand, rootlets, fine plant residues, etc. can easily be seen. Water is instantly absorbed by these aggregates; most of them disintegrate after capillary action. Soils under grass contain much less aggregates of the coprolitic type than the uppermost layer of soils in flood-plain oak stands.

Water stability is due, of course, to a number of factors, the most important being the nature and properties of those binding materials by which the separates are cemented to the structural units. There is an extensive literature on the problem, which was briefly reviewed by Kachinskiy two years ago (12).

To study the stability of flood-plain soil aggregates, we employed the method of combined microscopic and colloid chemical investigation of soil structure developed by Antipov-Karatayev, Kellerman, and Khan (1).

According to these investigators, the maximum stability is possessed by aggregates in which both the primary bonds (between the ultimate particles) and the secondary bonds (between the microaggregates) are caused by the adsorption of humic substances in the between packet spaces of the clay particles. These are highly stable aggregates of the "humic" type. The least stable — aggregates of the friable humate-clay type — have primary bonds caused by polar adsorption of humic substances on clay particles through exchangeable cations or inorganic groups of sesquioxides, while the secondary bonds are caused by polar-surface-adsorbed humic substances.

In the medium stable, i. e., iron-clay-humic type of aggregates, the primary bonds are caused by humic substances adsorbed on the inner surfaces of the clay particles, while the secondary bonds are caused by iron (aluminum) hydroxides or iron-humate complexes.

The method of Antipov-Karatayev, Kellerman, and Khan (1) provides for a step-by-step processing of structural aggregates with an alcohol-benzene mixture, alkaline buffer solution ($0.1nNaOH + 0.1nNa_2C_2O_4$). Tamm's reagent ($H_2C_2O_4 + (NH_4)_2C_2O_4$, solution pH 3.2), again with the alkaline buffer solution and, finally, repeated processing with sodium hypobromite. These reagents break up the soil aggregates, but the sequence and degree of destruction differ depending on the type of bonds. The aggregates are observed under the microscope as the destruction proceeds. The content of humic acids and fulvic acids, iron, aluminum, and silicilic acids is determined in the binding material freed from the aggregates by the reagents; the content of carbon "humins" is determined in the residue of the aggregates after processing with the reagents. The resultant data are the basis for appraising the structural properties of the aggregates and the binding material contained therein.

We studied soil aggregates diameters of 1-2 and 2-3 mm from the uppermost horizons of the four varieties of flood-plain soils described previously.

It turned out that the structural aggregates from the flood-plain oak stand were much more resistant to the disintegrating action of the chemical reagents than those from the soils under grass. The following is a brief description of the process:

Flood-plain sod soil	Flood-plain sod-forest soil
Profile 1, horizon A 0-3 cm, fraction 2-3 mm	Profile 2, horizon A_1 1-7 cm, fraction 2-3 mm
Treatment with an alkaline buffer solution	
Most of the aggregate disintegrates into microaggregates and mineral grains	Most of the aggregate retains its form or disintegrates into two or three microaggregates
Treatment with Tamm's reagent	
Disintegration of the microaggregates continues, color of the particles lightens	Further destruction of the aggregate is almost imperceptible
Second treatment with an alkaline buffer solution	

Gradual destruction of remaining microaggregates	Mineral grains fall out from part of the aggregate, part of the aggregate retains its form and contours
Treatment with sodium hypobromite	
Destruction of all the aggregate down to ultimate particles	Destruction of most of the aggregate down to ultimate particles

We observed similar differences while comparing sod-meadow soils (Profile 3) with sod-meadow-forest soils (Profile 4) and while studying the disintegration of 1-2 mm diameter aggregates in all four soil varieties.

It is quite clear from the foregoing data that most of the structural aggregates from sod and sod-meadow soils were largely destroyed during the first treatment with a buffer solution, whereas the structural aggregates from the uppermost soil horizons of the flood-plain oak stand were perceptibly destroyed in most cases only after oxidation of the humic substances by repeated treatment with sodium hypobromite. This suggests that the aggregates from sod and sod-meadow flood-plain soils, judging by the nature of the destruction, should be classified, according to Antipov-Karatayev and others (1), with the unstable friable humate-clay aggregates. Structural aggregates from sod-forest and sod-meadow-forest soils of flood-plain oak stand, represented mainly by the coprolites of earthworms, are much more stable and, judging from the nature of the destruction after processing with chemical reagents, belong with the highly resistant humic aggregates.

Analysis of the "binding" material (Table 6) did not yield as clear-cut a picture of the difference in structure between flood-plain forest soils and flood-plain meadow soils. Nevertheless the data indicate that the structural aggregates of oak soils contain more firmly bound organic matter (cf. the "humin" fraction) and less easily freed by alkaline reagents than the aggregates of meadow soils. The difference in composition of binding material may well have been more pronounced if aggregates of the coprolitic and noncoprolitic types were compared. In our samples coprolites were more dominant in oak soils than in meadow soils.

In view of the fact that Tamm's reagent does not seem to have much of an effect on disintegration of the structural aggregates and freeing of their organic matter, the bonds created by the sesquioxides play a minor role in the structural aggregates of the soils under investigation. At the same time there is a noteworthy increase in the content of available iron in aggregates from sod-meadow and sod-meadow-forest soils (i. e., soils periodically but briefly influenced by ground water) as compared with sod and sod-forest soils. It is quite possible that bonds created by sesquioxides will play a much more significant role in the aggregates of the Klyaz'ma River flood-plain meadow soils.

The low ratio of humic to fulvic acids, as shown by the analytic data in Table 6, is also noteworthy. There are grounds for believing that this is characteristic of the humic matter of flood-plain soils in the forest zone. This may well be linked to the comparatively rapid loss of structure by flood-plain soils from plowing and use for cultivated crops. There are several references in the literature to this property of flood-plain soils (4, 18).

The water stability of structural aggregates and resistance to chemical reagents depend, of course, not only on the composition of the bnding materials but also on the process by which the aggregates are formed. It was noted previously that earthworm coprolites are predominant among structural aggregates from the uppermost horizon of flood-plain oak soils. The soil mass becomes saturated with mucus as it passes through the intestinal tract of the worm and is shaped by its muscular force. The result is complete mixing of the soil mass and formation of numerous and close contacts between all its components, which undoubtedly binds them together more solidly in the coprolitic aggregate.

An examination of plane-parallel sections of structural aggregates under the polariscope clearly revealed that coprolitic aggregates have a more even distribution of humic substances throughout along with denser packing of ultimate particles and microaggregates in comparison with structural aggregates of the noncoprolitic type.

A study of 5-7 mm aggregates from the same soils (by the fixation method in five replications) showed that forest-soil coprolitic aggregates are somewhat less proous (32.2%) than sod-meadow soil noncoprolitic aggregates (37.7%). Compactness of the coprolitic aggregates does not reach the point, however, where inactive porosity predominates in the soil aggregate. There are actually fewer large pores and cracks in the coprolitic aggregates of the soils under investigation than in the noncoprolitic aggregates, but they have a dense network of fine pores for the most part 0.01-0.1 mm in size. Inactive porosity is the result of pores smaller than 0.01 mm in diameter, according to Kachinskiy (11).

P. U. Bakhtin and M. N. Pol'skiy (2), after investigating the water stability and porosity of sod-podzolic soil coprolitic aggregates, came to the conclusion that coprolites have high water stability and have about the same porosity as noncoprolitic aggregates with a tendency toward greater porosity.

Although earthworm coprolites long ago attracted the attention of many investigators as highly unusual structural aggregates, all their properties have not as yet been fully elucidated. The recent research of Ponomareva (14), Sokolov (15), and Zrazhevskiy (10) has shown that coprolites vary with the nature of the plant residues used by the worms as food, the species of worms forming the coprolites, particle size, and mineralogical composition of the mineral mass ingested by the worms. Ponomareva (14) found, for example, that the coprolites of worms feeding on oak leaves do not contain calcareous concretions, even though oak leaves have more calcium than do the grasses under which coprolites contain

Table 6

Composition of "cementing" material in structural aggregates

Profile No.	Soil	Horizon and depth, cm	Aggregate diameter, mm	Content of total carbon as a%	Carbon as a % of the total amount						C of humic acids / C of fulvic acids	Content of available iron as a %
					Fraction I		Fraction II		Fraction III			
					Humic acids	Fulvic acids	Humic acids	Fulvic acids	"humin"	Total		
1	Sod	A 0—3	3—2	3,37	22,69	34,17	5,01	3,77	31,23	96,87	0,73	1,99
			2—1	3,42	20,55	30,89	4,35	2,05	33,15	90,99	0,76	2,01
2	Sod-forest	$A_1$1—7	3—2	4,49	19,58	28,65	4,86	3,43	37,30	93,82	0,76	1,75
			2—1	4,86	17,48	26,82	4,03	2,20	39,16	89,69	0,74	1,67
3	Sod-meadow	A 0–6	3–2	4,44	26,34	24,24	3,15	2,60	34,62	90,95	1,10	3,53
			2—1	4,52	26,89	28,15	3,36	1,94	34,41	93,80	1,00	3,24
4	Sod-meadow-forest	$A_1$1—8	3—2	6,06	20,23	25,80	3,88	2,47	39,50	91,88	0,85	3,20
			2–1	6,00	18,92	20,15	3,86	2,76	40,17	85,16	0,96	3,23

Note: Comma represents decimal point.

calcite. Coprolites in the Klyaz'ma River flood-plain soils both under oak stand and under meadow vegetation contain no calcite.

Returning to our comparison of the soil structure of flood-plain oak stands and flood-plain meadows of the Klyaz'ma River valley, we have no hesitation in attributing the exceptionally high structural condition of the soils in the light flood-plain oak stands of the river bed and ridgelike central flood plain and the marked water stability of their structure to the vast amount of earthworm coprolites that they contain. Allolobophora calliginosa, very active in the ~~formation of structure, is~~ the commonest species (7).

According to Charles Darwin, a large part of the soil has more than once passed through the intestinal tract of worms so that the terms "animal layer" and "plant layer" can be applied to the soil. This usage is undoubtedly justified in connection with the upper horizons of the sod-forest soils of flood-plain oak stand. Their structure, we firmly believe, is as much zoogenic as it is phytogenic, because it is largely created by the activity of earthworms. Müller recently called attention to this role of earthworms in flood-plain forest soils (19).

It must be borne in mind, however, that flood-plain forest soil coprolites are concentrated in the uppermost section of the humus-accumulative horizon lying directly under the forest litter. We have designated this portion of the horizon with the symbol A_1' and observed it in all the sod-forest and sod-meadow-forest soils of flood-plain oak stand. This subhorizon was formed by the rich litter of oak forests providing nutrients for many soil animals while acting as a mulch to protect the uppermost horizon and the animals inhabiting it from loss of moisture and the direct rays of the sun. The vital activity of the soil fauna and microflora is concentrated in this horizon (A_1').

The vital activity of the fauna and microflora is not as concentrated in the uppermost horizon of the soils under the grass of flood-plain meadows, because the grass residues (chiefly dead roots) are found not only on the soil surface but also in the horizon proper where they are distributed more evenly and to a greater depth. This explains the aforementioned difference in structure of the humus-accumulative horizon of flood-plain forest soils as compared with the flood-plain meadow soils.

The peculiarities of formation and structure of flood-plain forest soils described in this paper apply to sod-forest and sod-meadow-forest soils in the light flood-plain oak stand of the river-bed and ridgelike central zones of the flood plain. Meadow-forest soils in wet oak stands, not to mention mixed oak-elm flood-plain forests in the low-lying areas of the central flood plain, are quite different in structure. The properties of flood-plain soil structure are closely connected with their genesis.

Conclusions

1. The structural condition of sod-forest and sod-meadow-forest soils in flood-plain oak stands of the river-bed and ridgelike parts of the central flood plain is higher than that of mixed-grass meadows on the same flood-plain features.

2. In sod-forest and sod-meadow-forest soils of flood-plain oak stand only the uppermost layer of the humus-accumulative horizon (A_1') lying directly under the forest litter has a high structural condition. It contains almost the entire humus content and is the main area for the vital activity of the soil fauna and microflora.

3. The structural condition of the upper horizon of sod and sod-meadow soils in flood-plain meadows is lower than that of soils in flood-plain oak stands, but the thickness of the structured layer is greater, which corresponds to the more gradual decrease in amount of humus and plant residues (chiefly roots) in the profile of soils under grass as compared with soils under flood-plain forests.

4. The soil structural aggregates of flood-plain oak stand consist mainly of earthworm coprolites, concentrated for the most part in horizon A_1' lying just under the forest litter. The soils of flood-plain meadows contain fewer coprolites than do the soils of flood-plain oak stand, but they are distributed throughout the profile more evenly and to a greater depth.

5. The soil structure of flood-plain oak stand is characterized by high water stability. The coprolitic aggregates have a dense network of pores among which those 0.01-0.1 mm in diameter predominate; they have fewer large pores and cracks than do the noncoprolitic structural aggregates.

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DEPTH OF WETTING OF CHERNOZEM SOILS AFTER IRRIGATION

I. P. SUKHAREV, Kursk Agricultural Institute

The depth to which the soil may become wet is of considerable importance in irrigation and hydrological investigations. The amount of water absorbed indicates the depth of penetration only indirectly and approximately. It is generally believed that 1 mm of water generally wets the soil to a depth of 1 cm. However, the depth varies with the moisture content of the soil, its physical condition, and the amount of rain. The greater the moisture content, the more quickly does the water penetrate and, vice versa, with low moisture content part of the water absorbed is used to increase the moisture content in the soil and saturate it to its field capacity before penetrating more deeply. Many Soviet scientists have studied this problem (1, 2, 3, 7 and others). Although there has been fairly detailed treatment of moisture intake published data on the depth of wetting are still meager [Preobrazhenskaya (7), and others]. To date an accurate method of determining it has not been devised. Several investigators have tried to measure the depth of wetting by sampling the soil to the depth reached by irrigation water. This method is useful in determining the maximum depth of wetting at a given rate of irrigation, but it does not reflect the dynamics of wetting with time and the rapidity with which the water penetrates.

Owing to the great importance of the dynamics of soil wetting in melioration, soil science, and hydrology, and to the fact that the problem has been scarcely studied, we ran a series of experiments (1949-1954) on the Kamennaya Steppe irrigated crop rotation field belonging to the Dokuchayev Institute of Agriculture. The field is located on a northeast slope. The soil is all ordinary chernozem 0.6-0.8 m thick underlain by deposits of clay loam. The ground water is 6-9 m from the surface. Some two years ago we published the results of experiments on the entry of water into different kinds of farm land involving a variety of agricultural practices (9).

We conducted experiments in the summer of 1949 on a field of spring wheat, on grasses, and fallow to determine the depth of soil wetting when 60, 70, 80, and 100 mm of water were applied. The plots were 2 m x 2 m in size with a double wooden frame enclosure. All the plots were flooded at the same time. The water was measured with a 10-liter marked cylinder. After flooding the plots, we covered them with straw to prevent moisture loss by evaporation. We determined the depth of wetting by sampling into the experimental plots at 10 cm intervals. 4, 24, and 48 hours after flooding (Table 1). The table shows that the depth to which the soil is wet varies with its moisture content. If the moisture content is low, the depth is slight even if a good deal of water is applied. The depth of wetting increases with the amount of moisture present. The depth varies on fields of spring wheat, alfalfa, and on fallow (long cultivated land). The greatest specific wetting took place on the fallow, i. e., wetting of the soil in proportion to the unit depth of water (in mm), the least on the alfalfa field. The depth of wetting correlates well with the original moisture content of the wetted soil horizons. On the spring wheat field, moisture in the 0-20, 20-50, and 50-100 cm layers was 46%, 74%, and 73%, respectively, of the maximum field moisture capacity. On the alfalfa field in the same layers, the moisture before the experiment was 27%, 52%, and 81% and 48%, 84%, and 82% on the fallow. The moisture corresponding to the maximum field moisture capacity of these layers of ordinary chernozem constitutes 39%, 32.5% and 30%, respectively, of the dry soil weight. The mean depth of wetting by 1-mm depth (specific wetting) of water on fields of spring wheat, alfalfa, and fallow was 1.32, 0.94, and 1.61 cm, respectively.

We conducted a series of experiments in 1952, 1953, and 1954 in the same crop rotation to study the dynamics of soil wetting, using tensiometers to determine the depth. Tensiometers are highly sensitive to the slightest changes in moisture. As soon as water reaches the tip of the instrument, the scale of the mercury manometer immediately shows a sharp drop in pressure. We used tensiometers designed by the Dmitrovskiy Observation Station, All-Union Research Institute of Hydraulic Engineering and Melioration and set them 5, 15, 25, 50, 100, 150, and 200 cm in the soil. Shishkov (10) has described the instrument in detail and the way it should be used to determine soil moisture. We present herewith an account of our experiments on soil wetting.

Experiment 1. Performed August 29, 1952 on the stubble of spring wheat. Six tensiometers were set 5, 15, 25, 50, 100, 150 and 200 cm into the earth in the spring of 1952. A level area was laid out around the tensiometer and enclosed with a wooden frame 160 x 160 cm (2.56 m²). A ridge of earth 15-20 cm high was placed 50 cm from the sides of the frame along

Table 1

Wetting depth of ordinary chernozem on different fields in an irrigated crop rotation

Rate of wetting, mm	Average weight of moisture content before the experiment as a % by layers, cm			Depth of wetting of soil after irrigation, cm			Wetting of soil in cm by 1 mm of water
	0-20	20-50	50-100	4hrs.	24hrs.	48hrs.	
			Field of spring wheat				
60	17,8	24,3	21,8	50	75	90	1,50
70	17,4	23,9	21,6	45	80	100	1,42
80	17,5	24,1	21,8	70	100	105	1,32
100	17,2	23,7	21,3	65	100	108	1,08
			Field of alfalfa				
60	10,5	17,6	17,4	30	50	55	0,92
70	11,1	16,9	17,2	50	60	60	0,85
80	10,8	17,1	17,5	50	80	90	1,10
100	10,0	17,3	17,1	60	85	—	0,85
			Fallow field (long cultivated)				
60	18,7	27,4	24,4	90	100	—	1,67
70	18,1	26,7	24,6	105	115	120	1,71
80	17,8	27,1	24,0	115	130	135	1,68
100	17,7	27,3	24,1	120	137	144	1,44

Note: Comma represents decimal point.

its outer perimeter. The place was dug out and carefully leveled off prior to the experiment. The wooden frame was set 15-18 cm into the soil. Water depth of 5 cm was poured from a graduated cylinder into the inner compartment, the amount being carefully checked. Between the frame and earth ridge the water level was kept at the same depth as in the compartment. The water entered the soil without any lateral flow because of the enclosure.

When the level dropped 1 cm, more water was poured into the compartment until a level reached 5-cm depth. The experiment was begun at 10:35 a. m. and ended at 1:26 p. m., i. e., it lasted 171 minutes. The water intake was observed during the experiment and the depth of wetting read from the tensiometers. As soon as the water reached the tip of the tensiometer, pressure in the manometer dropped sharply with increased soil moisture. Tensiometers 1, 2, 3, 4, 5 and 6 were read at the previously mentioned depths 1, 6, 14, 18, 67, 117, and 126 minutes after the experiment started. The data of the first experiment are shown in Table 2.

Table 2 shows that wetting was fairly rapid in the 0-50 cm layer, very slow in the blanket clay loam underlying the chernozem layer. The top chernozem layer (0-50 cm) required 18 minutes and 74 mm of water; the 50-100 and 100-150 cm layers, owing to their low moisture content, required 49 and 50 minutes and 144 and 88 mm of water, respectively. Wetting of the 150-200 cm layer proceeded quite rapidly because of the cracks and comparatively high moisture content.

In Figure 1, A, B, and C are the curves of the total water intake by the plot, changes with time in the pressure of the tensiometers (in mm) at various depths, and the depth of soil wetting in relation to the water intake. Figure 1B shows that the pressure dropped sharply as the water reached the ceramic tips (filters) of the tensiometers. Some 340 mm of water (Fig. 1A) entered the soil during the experiment (171 minutes). As soon as the water touched the ceramic tips, the pressure in the tensiometers quickly attained values of 1-2 mm and ended by approaching zero.

It is evident from Figure 1C that the dynamics of soil wetting varies with the water intake. On chernozem soils the wetting zone spreads down fairly rapidly; below 150 cm, i. e., in the loess-like clay loam, the wetting zone increases more rapidly. This is due, as noted previously, to several cracks in the clay loam, to burrows of shrews and to their high moisture content.

Experiment 2 was set on September 9 and 14, 1953, on a field of grasses; on a grass field with young growth of winter crops (on occupied fallow); on the edge of a forest strip (meadow) and in a forest strip. At the end of May, 1953, tensiometers were inserted 5, 15, 25, 50, 100, 150, and 200 cm into the soil of these areas.

Table 2

Rate of soil wetting (stubble of spring wheat)

Observation	Tensiometer No.						
	1	2	3	4	5	6	7
Beginning of functioning of tensiometers from the start of the experiment, min.	1	6	14	18	67	117	126
Water entry, mm	6	28	40	74	218	306	320
Depth of soil wetting from readings of tensiometers, cm	5	15	25	50	100	150	200

Changes in the pressure of the manometers and moisture content of the various layers of soil were observed throughout the summer by sampling. On September 9, a water sprinkler (KDU-41) was placed on the grass field. The experimental plot was watered from one nozzle at the rate of 0.9 mm/min. The experiment took 210 minutes, lasting from 11:00 a. m. to 2:30 p. m. During this time 189 mm of water fell on the plot. The tensiometers were read every 3-5 minutes. A sharp drop in pressure showed that the water reached the tip (filter) of the instrument. Since tensiometer 4 got out of order on the grasses (at a depth of 50 cm), observations were made from Nos. 1, 2, 3, 5, 6 and 7 inserted 5, 15, 25, 100, 150 and 200 cm into the soil. Table 3 presents the composite data of observations of depth of soil wetting on the plot with grass.

Table 3 shows that the wetting of chernozems proceeded as rapidly with sprinkling as with a head of water used in Experiment 1. The plow layer required somewhat more than 1 mm of water to soak the soil to a depth of 1 cm. The loess-like clay loam underlying the chernozem required somewhat less water. Wetting to a depth of 100, 150, and 200 cm required 69.3, 108, and 166 mm of water, respectively. The rapidity of the process in this experiment was caused by the comparatively high moisture content of the experimental plot. Moisture in the one-meter layer during the experiment rose 195.3 mm. A 189 mm of water fell on the plot during 210 minutes.

The experiment was performed September 14 on the field with winter young crop, on the meadow (edge of forest strip no. 53), and in forest strip No. 53 (60-year-old stand). Water was supplied from the KDU-41 sprinkler at the rate of 0.9 mm/min for 90 minutes (from 9:22 a. m. to 10:52 a. m.). The total amount of water falling on the experimental plots was 81 mm. The manometers were read every 3-5 minutes. Five tensiometers were used on the winter crops and meadow (1, 2, 3, 4, and 5) and four in the forest strip (1, 2, 3, and 4); the others failed to work during the experiment. Table 4 presents the composite data of the observations in this experiment.

Table 4 shows that the character of soil wetting after sprinkling under winter crops, meadow, and forest strip is similar to that on the grass field. In Experiment 2 after sprinkling, wetting of the 0-50 cm layers proceeded as in Experiment 1 with a head of water on the ground; 50 cm below, the rate of wetting after sprinkling was more rapid than with a head of water (Experiment 1). A possible reason is that in Experiment 2 soil moisture was sub-

Table 3

Depth of soil wetting under grasses

Observation	Tensiometer No.					
	1	2	3	5	6	7
Beginning of functioning of tensiometers from the start of the experiment, min	8	16	35	77	120	185
Water entry, mm	7,2	14,4	31,5	69,3	108	166
Depth of soil wetting from readings of tensiometers, cm	5	15	25	100	150	200

Note: Comma represents decimal point.

Table 4

Depth of wetting of soil under a winter crop, meadow, and forest strip

Observation	Winter crop					Meadow					Forest strip			
	Tensiometer No.													
	1	2	3	4	5	1	2	3	4	5	1	2	3	4
Beginning of functioning of tensiometers from the start of the experiment, min.	8	28	43	58	88	8	24	28	44	73	8	28	43	58
Water entry, mm	7	25	39	52	79	7	22	25	39	65	7	25	38	52
Depth of soil wetting from tensiometers readings, cm	5	15	25	50	100	5	15	25	50	100	5	15	25	50

Note: Comma represents decimal point.

stantially higher than in Experiment 1, particularly in the 50-100 cm layer.

Experiment 3 was performed September 14, 1954[1] on a plot 10 x 10 m on field 4 of an irrigated steppe grain-technical crop rotation (of the Dokuchayev Institute of Agriculture). Low moisture contents were noted in the soil in the spring. The summer was hot and dry, especially after June 15. In 1954, the field was under spring wheat. After it was harvested, the experimental plot was carefully leveled out and enclosed with earth ridges 25-30 cm high. The outer enclosure was 1 m from the ridges. In the ecenter of the plot was a hydrogeological boring No. 17 put there in the fall of 1953. An embankment was built around the hole 1 m away to prevent the water from reaching the ground water between the sides of the hole and the earth. The experimental plot was supplied with water through a canal and water furrow located in the upper end of the plot. The flow of water was carefully controlled by a weir-watermeter. A head of water 10 cm deep was maintained throughout the experiment; when it dropped 2-3 cm, more water was added to bring it up to the original level. It was impossible to use tensiometers to determine the depth of soil wetting, but observations of the ground-water level from the hydrogeological boring permitted us to determine the rate of wetting of the entire layer of soil from the surface to the ground water (aeration zone). Before the experiment the water in the hole stood 6.5 m below the soil surface. Every 5-10 minutes during the experiment observations were made of the ground-water level. The experiment was begun at 10:30 a.m. and the intake of water continued until 11:00 p.m., totalling 482 mm. A rise of the ground water in the hole was noted at 2:50 p.m. Before the rise 356 mm of water entered, during the rise, 126 mm. The soil was covered with 20-25 cm of straw after the watering to prevent evaporation.

Figure 2, A and B, show that the soil was wetted to a depth of 6.5 m in 4 hours and 20 minutes after start of the experiment (beginning of the rise of the ground water). The average rate of wetting was 1.35 cm per minute. An average of 1 mm water wetted 1.8 cm of soil. Taking into account a 4.7 m thickness of the soil minus the capillary zone, 1 mm depth of water wets 1.32 cm of soil. This is close to the figure for soil wetting cited in Table 1.

The important practical conclusion to be drawn from these data is that when the water table is 6-10 m from the surface, the safe rate of irrigation to prevent the rise of ground water is expressed by the following relationship:

$$m \leqslant 0.54H,$$

where m is the safe rate of irrigation to prevent a rise of ground water (in thousands of m^3/ha) and H is the thickness of the aeration zone (distance from the surface to the ground water) in meters.

If the water table is less than 5 m from the surface:

$$m \leqslant 0.76\,(H-h),$$

where h is the height of the capillary rise in meters for the given soil.

It will be noted that these calculations are valid for uniform irrigations. Frequently, however, a rise of ground water is caused by uneven irrigations, excessively wetting the low-lying areas.

The previously mentioned relationships can be used to calculate the rate of fall irrigations to recharge the moisture content in chernozem

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[1] Experiment 3 was performed by our co-worker Ye.M. Sukhareva.

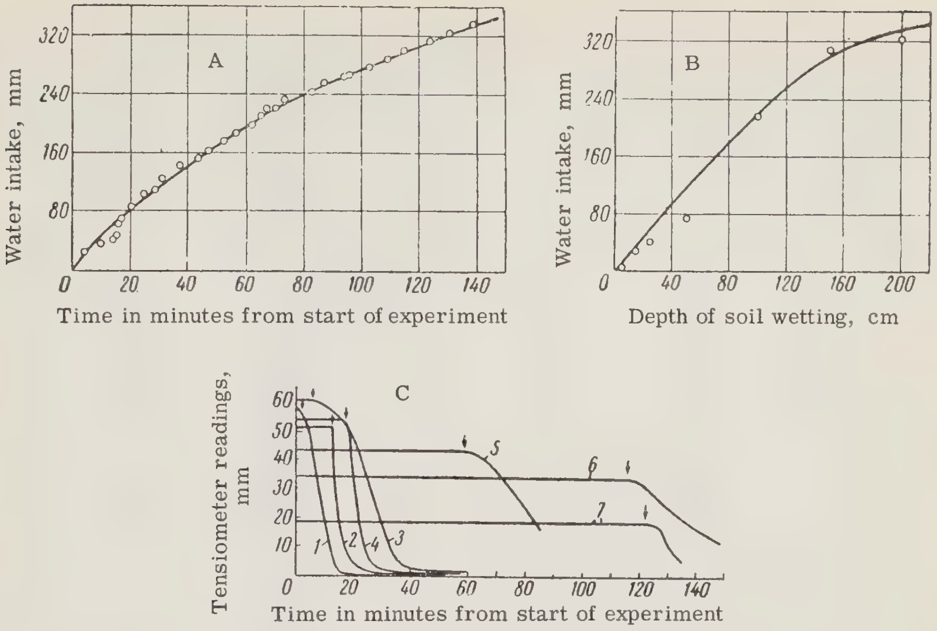

Fig. 1. - Water intake and wetting of soil.

A - curve of water intake; B - change in pressure of tensiometer (in mm) under the influence of infiltrating water. 1 - No. 1-5 cm; 2 - No. 2-15 cm; 3 - No. 3-25 cm; 4 - No. 4-50 cm; 5 - No. 5-100 cm; 6 - No. 6-150 cm; 7 - No. 7-200 cm. The arrow designates the start of the drop in pressure of the tensiometer. C - dynamics of infiltration of soil (in cm) in relation to the amount of water absorbed (in mm) with constant depth of water (flooding).

soils. During our initial observations the ground water level rose rapidly, then more slowly as the rate of water intake slackened. The general ground water level at the end of the period of water intake was 3.75 m. The rapid rise of ground water at the beginning of the observations is explained by the fact that it occurred in the capillary fringe where the soil is moistened to the capillary moisture capacity and therefore has low water discharge. Even in sand, water discharge in the capillary zone does not exceed 1%; in clay loams it is even lower. In the clay loams in our experiment the capillary rise zone was 1.8 m.

Table 5 presents data on water intake during the rise of the water table and water discharge of the soil in the zone of water table rise. It shows that while the water table was rising, the amount of water absorbed continued to decrease; the rise of the water table also proceeded on a falling curve. The water discharge coefficient of the soil steadily increased along the top of the soil column starting with the original ground water level; the value was lowest in the layer of soil up to 1.8 m (from the ground water level), i. e., in the capillary zone.

Water discharge in the uppermost part of the saturated soil layer from 3.55 to 3.75 m from the original ground water level was 0.05 (5%). The slight variation in water discharge along the top of the soil column is explained by the heterogeneity, abundance of cracks, and presence of many animal burrows in the loess-like clay loams. Owing to the low water discharge of loess-like clay loams, a slight infiltration of rain or thaw water raises the ground water level considerably.

Figure 2, C, is a graphic representation of the relationship between the amount of water intake in Experiment 3 (from the beginning of the rise of the ground water level) and the extent of rise of the ground water. It shows that 2.5 mm of infiltrating water raises the ground water level in the capillary zone 20 cm, while 10 mm causes a rise of 50 cm, etc.

For several days after the experiment ended — September 15, 16, 18, and 20 — we observed the soil moisture content in 0-300-cm depth. We found that as early as the second day, September 15, moisture spread steadily and uniformly. On September 24, we took soil samples to determine the moisture content of the entire aeration zone, i. e., to the ground water level. Since the plot was covered with straw, none of the moisture was lost by evaporation as it seeped down into the deeper horizons and reached the ground water.

Table 6 contains data on changes in moisture content with time through the soil horizons from the surface to the ground water. It is evident from the table that most of the moisture was

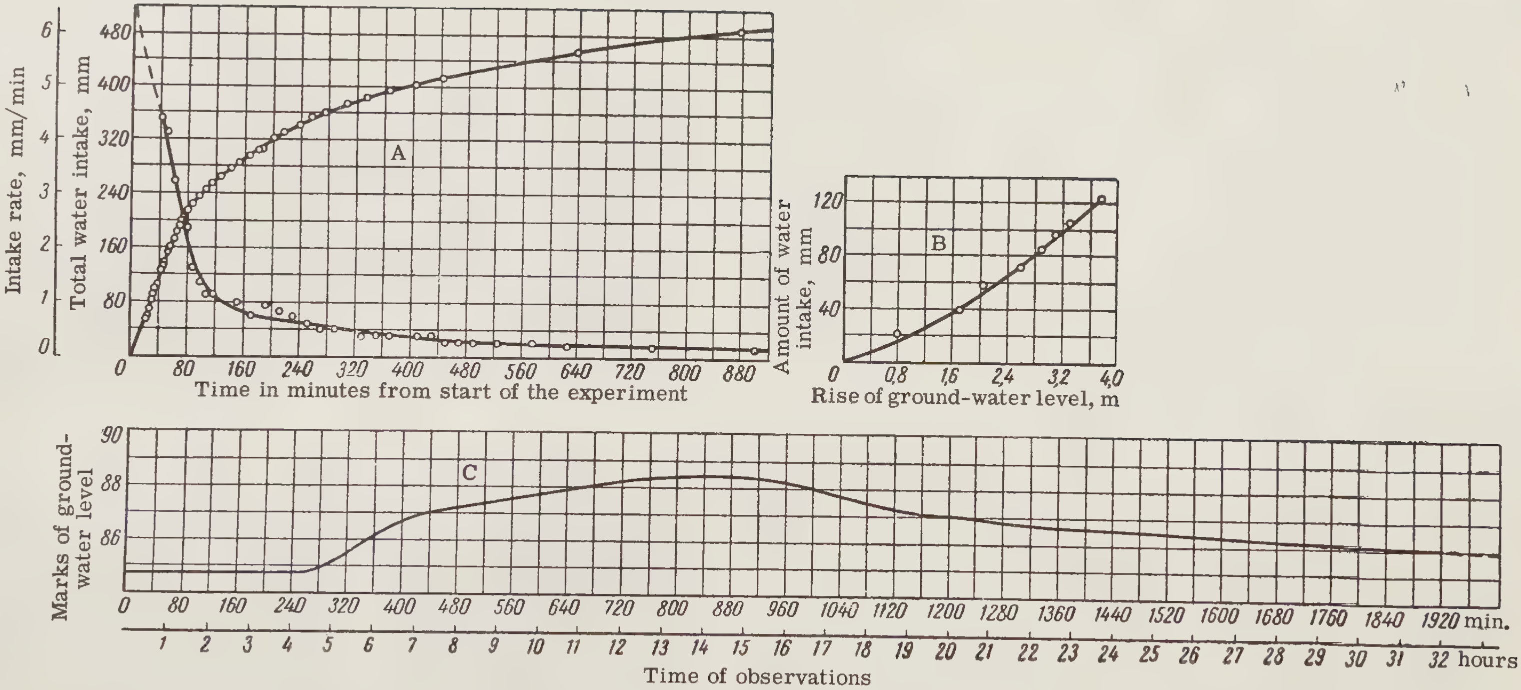

Fig. 2

A - Water intake on an experimental plot; B - rise of water table during the intake, and its drop after the experiment; C - Rise of water table in relation to the amount of percolating water during the period starting with the rise of the water table (after saturation of the aeration zone).

Table 5

Water intake by clay loam in the capillary rise zone of water table

Time from the start of rise of water table, hours	Amount of water intake during this period (P)	Δp,in *мм*	Rise of water table H, m	ΔH in *м*	Coefficient of water discharge $\delta=\frac{\Delta P}{\Delta H}$
0	—	22	—	0,80	0,026
1	22	18	0,80	0,90	0,020
2	40	18	1,70	0,55	0,032
3	58	14	2,25	0,35	0,040
4	78	12	2,60	0,30	0,040
5	84	12	2,90	0,20	0,060
6	96	8	3,10	0,20	0,040
7	104	8	3,30	0,25	0,032
8	112	10	3,55	0,20	0,05
9	112	4	3,75	0,00	—
10	126	—	3,75	—	—
	126		3,75		0,034 (mean)

Note: Comma represents decimal point.

Table 6

Moisture content in the soil of an experimental plot, mm

Periods of observations	Soil layer, cm							Total moisture content in the 0-650 cm layer, mm
	0–100	100–200	200–300	300–400	400–500	500–600	600–650	
Experimental plot								
Sept. 15	337,6	284,4	325,4			Not det'd.		
Sept. 16	363,5	261,2	300,4	"	"	"	"	
Sept. 18	305,6	288,6	312,2	"	"	"	"	
Sept. 20	326,8	310,6	317,2	"	"	"	"	
Sept. 24	314,8	345,8	344,8	293,2	337,0	335,2	115,2	2075,2
Control before the experiment								
	183,4	231,8	272,2	278,8	328,8	327,8	117,4	1740,2
Increase of moisture as compared with the control								
Sept. 15	155,2	52,6	53,2		Not det'd.			261,0
Sept. 16	180,0	29,4	28,2	"	"	"	"	237,0
Sept. 18	122,2	56,8	40,0	"	"	"	"	219,0
Sept. 20	143,0	79,8	45,0	"	"	"	"	267,0
Sept. 24	131,4	114,0	72,6	14,0	8,2	7,4	0,0	345,2

Note: Comma represents decimal point.

retained in the top 3-meter layer; below and to the actual ground water level it was close to the maximum field moisture capacity. Since only small amounts of moisture accumulated in these lower layers, the process of capillary discharge was rapid. Between September 15 and 24 there was a marked decrease in moisture in the 0-300-cm layer from the seepage downward.

The data in Table 6 show that the moisture content on September 24, i. e., the tenth day from the start of the experiment, in the 0-650 cm layer on the experimental plot was 342.5 mm more than on the control (before the experiment). Thus, the rise of ground water in the experiment occurred only after 356 mm of water had been absorbed, i. e. after saturation of the aeration zone to maximum field moisture capacity.

Conclusions

1. Kamennaya Steppe chernozem soils have a high water permeability. The one-meter layer is wetted after 70-80 mm of water enters the ground. The amount of moisture in the soil greatly affects the depth and rate of wetting. When the moisture content of the 0-20-, 20-50-, and 50-100 cm layers was 27%, 52%, and 81%, respectively, of the field moisture capacity, 1-mm depth of water in the experiments wetted the soil to an average depth of 0.94 cm; when their moisture content was 46%, 74%, and 73% of the field moisture capacity, 1 mm depth of water wetted the soil to an average depth of 1.32 cm. On fallow with higher moisture content (48%, 84%, and 82% of the field moisture capacity), 1 mm depth of water wetted the soil to an average depth of 1.61 cm.

2. Vertical wetting of the soil with time can be studied by means of a soil tensiometer designed by the Dmitrovskiy Observation Station, All-Union Research Institute of Hydraulic Engineering and Melioration. When water reaches the tip of the tensiometer, pressure in the manometer drops sharply, thereby indicating the boundary of the zone of soil wetting. The effect was the same whether the water was applied by sprinkling or by a depth of water. With the latter, the top meter of soil was wetted within 60-80 minutes.

3. The average rate of wetting the soil in the aerated zone 6.5 m thick (to the ground water) was 1.35 cm a minute. Exclusive of the capillary zone, 1 mm of water wetted an average of 1.34 cm of soil.

4. After the aerated zone is wetted to the field moisture capacity, subsequent wetting causes the ground water to rise, most rapidly at first in the capillary zone, where the coefficient of water discharge is very low (2%-2.6%). Water discharge increases above the capillary fringe, becoming 4%-5% in clay loam. Initially, 2.5 mm of infiltrating water caused the ground water to rise 20 cm. When the ground water rose 3.75 m, 126 mm of water seeped into it.

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SOIL MOISTURE CYCLE OF THE PLOW LAYER

A. M. BYALYY, Balashov Agricultural Experiment Station

Analysis of the extensive literature shows that the upper layer of the soil is an important regulator of the water regime of the entire soil profile. This influence on the water regime of the soils is evident in the following:

1. The cultivated upper layer contains a capillary network. At the boundary between this layer and the soil below with a natural structure there is an abrupt change in the structure of the soil capillaries. They become discontinuous, and this means reduced flow of water toward the surface of the soil and, by the same token, reduced evaporation thereof (29, 17, 19, 11, 7, etc).

2. Cultivation of the upper layer reduces its thermal conductivity retards the warming of the lower layers, and reduces the amplitude of the temperature fluctuations in them. As a result, evaporation losses are reduced, and water is accumulated from condensation (20, 24, 30).

3. The upper layer of the soil is a special kind of porous membrane that retards the diffusion of water vapor into the atmosphere and thus tends to reduce the rate of evaporation of the soil moisture.

4. Finally, there is a point of view which holds that tillage of the upper layer has a bad effect on the water regime of the soil. Breaking up the soil increases evaporation, and hence the average moisture content of cultivated fields is less than for fields that have not been cultivated but only weeded (25, 26, 31, etc.).

The capillary theory of water movement is as old as the theory of soil cultivation. It has been criticized by Kossovich, who, on the basis of careful investigations, came to the conclusion that: "soil moisture at the level of the minimum moisture capacity cannot move in the liquid state" (16). With diverse slight modifications and variations, this point of view was also held by Rotmistrov, Tulaykov, lebedev, Lipman, Weihmeyer, Shaw, Insraelson, Fageler, Mattson, Adam, Frantseson, Ioffe, and others (24, 26, 20, 30, 31, 27, 21, 3, 28, 12).

The revival of the theory of the movement of suspended water was the work of A. A. Rode and co-workers. In contrast to their predecessors, Rode, Abramova, and Bol'shakov (2, 4, 23) gave quantitative expression to this process.

These authors have established that in microstructural clay loams and clayey soils and soil materials of silty texture, up to one third of the field capacity can move to the evaporative surface. In fine clay loam and clayey soils, having a granular or blocky structure, an insignificant amount of the suspended water can move upward with evaporation (1). This conclusion is very important for a knowledge of the behavior of soil moisture in chernozem.

The papers of Kolyasev, Deryagin, and Mel'nikova (14, 9, 15) are of much importance in establishing the principles and mechanism of water movement. These authors hold that the amount of moisture in a soil determines the mechanism and rate of water movement in it. Until a particular moisture content is reached, the soil dries at a constant rate, but then the rate of drying is reduced, and film-meniscus, film-osmotic, and diffusion mechanisms take over, depending on the moisture interval.

A combination of current views on the water movement (23) and moisture differences in the soil (14) makes it possible to generalize the experimental data compiled by experiment stations in the Southeast on the water regime of the soil in general and the moisture cycle of the plow layer in particular.

In the present paper we give soil moisture data obtained in an eleven-field crop rotation located at the seed-selection farm of the Southeast Agricultural Institute of the USSR in Saratov. The soil is an ordinary chernozem, low in clay.

The basic soil moisture determinations were made in the fields of the crop rotation at a depth of three meters. In the intervals between the basic determinations the study was limited to the layers at 1.5 m, 100 cm, and 30 cm.

Borings to 150 and 300 cm were replicated three times. In this case the accuracy of the determinations was in the range of 1.5%-2%. In the investigation of the moisture cycle in the plow layer the number of replications varied from five to ten, with an accuracy of determination within 0.5%-1.0%.

Soil Moisture in Black Fallow

Data on the dynamics of soil moisture in black fallow is of definite interest in determining the movement of suspended soil moisture. In the experimental crop rotation, soil moisture was studied in two black fallow fields. One of these fields was left fallow after a crop of spring wheat on twice-plowed land after sod, and the second was the final field in the fallow-row crop sequence of the crop rotation. The black-fallow fields remained almost completely bare of vegetation throughout the entire spring and summer until the winter crops were sown (August 25-September 1).

To facilitate presentation of the experimental data, they have been arranged according to groups of years with similar weather conditions. During the 13 years of the investigations (1941-1953), two years (1944-1945) were favorable as regards moisture in the spring and summer; seven years (1941, 1942, 1947, 1949-1952) were average; and four years (1943, 1946, 1948, and 1953) were dry. The data on soil moisture in black fallow for the years with favorable moisture conditions are given in Table 1.

The initial water reserves in the black fallow in the spring of 1944 were low. Only in the layer from 0-100 cm did they approach the maximum field capacity. During the fallow period (from April 15 to August 28), the soil moisture fluctuated in the 0-100 cm layer. In all the other horizons it increased during the fallow period. The dry weather continued after the sowing of winter wheat from August 28 to September 3, 1944. There was an appreciable decline over almost the entire soil profile during this period (112.2 mm), associated not only with absorption by the winter wheat but also with water losses to evaporation.

In 1945, moisture declined 143.1 mm between April 18 and June 4. In this time the soil moisture in one case (field No. 5) increased by 91.4 mm in the layer from 0-150 cm, and in another (field No. 8), by 96.9 mm. June was dry. In the period from June 4 to 29 there was 27 mm of precipitation in the form of brief, light rains. During this period the moisture of the layer from 0-150 cm declined 54.2-67.6 mm. The moisture reduction in this layer was apparently associated not only with evaporation but also with movement of gravity water to the deeper soil layers. The subsequent period was one of rainy weather, which meant replenishment of the water content over the whole soil profile.

During the years with favorable moisture conditions, in all three instances observed there was an accumulation of soil moisture during the fallow period amounting to 55-161 mm.

Data for seven years on the dynamics of soil moisture in black fallow under average moisture conditions are given in Table 2. These data show that, in the years with a reduction in the available moisture, the moisture contents of the deeper soil layers did not decline during the fallow period; in most cases it increased. The moisture of the layers from 0-50 cm and in part from 50-100 cm underwent change. During the seven years, we observed in five cases moisture increases in black fallow amounting to 32-133 mm; in three cases black fallow did not show moisture accumulation; and in one case there was a loss of 37 mm of the spring moisture content during the fallow period. In this case, again the basic losses occurred from the 0-100 cm layer. These data

Table 1

Soil moisture in millimeters in favorable years

Position of black fallow in crop rotation	Field No.	Year of observation	Date	Depth, cm						
				0–50	50–100	100–150	150–200	200–250	250–300	0–300
After spring wheat on twice-plowed land after sod	C-3	1944	April 15	151,7	148,0	125,3	107,1	117,3	123,1	772,5
			June 5	136,6	137,7	129,5	—	—	—	—
			July 12	147,4	154,0	150,5	149,2	—	—	—
			Aug. 28	142,5	145,0	144,7	169,9	126,5	154,0	882,6
			Sept. 3	96,6	125,5	142,3	—	—	—	—
Fallow-row crop sequence	C-5	1945	April 18	160,2	113,2	121,5	125,3	142,1	147,6	809,7
			June 4	171,3	157,7	157,3	—	—	—	—
			June 29	153,7	145,9	132,5	141,5	137,9	141,9	853,4
			Aug. 31	159,6	145,0	160,8	174,7	166,8	163,9	970,8
			Sept. 4	170,7	148,0	162,7	140,9	—	—	—
After spring wheat on twice-plowed land after sod	C-8	1945	April 20	157,0	106,5	129,2	140,9	149,7	149,8	833,1
			June 4	165,5	156,1	137,0	—	—	—	—
			June 30	155,8	137,9	127,3	—	—	—	—
			Aug. 31	158,4	141,3	154,6	150,3	146,1	141,4	892,1
			Sept. 6	168,1	149,0	145,9	137,4	—	—	—

Note: Comma represents decimal point.

Table 2

Soil moisture in millimeters for years of average moisture

Position of black fallow in crop rotation	Field No.	Year of observation	Date	Depth, cm						
				0–50	50–100	100–150	150–200	200–250	250–300	0–300
Fallow-row crop sequence	C-5	1941	May 4	164,8	134,5	106,2	113,7	112,2	123,5	755,4
			July 4	157,8	136,7	139,7	151,2	145,1	140,7	871,0
			Sept. 10	203,8	160,3	167,8	—	—	—	—
The same	C-6	1942	May 29	161,6	161,6	152,6	163,3	162,7	158,4	960,2
			Oct. 5	149,4	145,1	159,3	168,8	163,6	161,2	947,4
The same	C-2	1947	April 21	166,8	163,2	154,7	154,8	152,2	137,9	929,6
			July 7	149,8	158,8	151,5	144,9	143,9	143,9	892,8
			Aug. 30	160,8	161,4	156,1	148,6	147,9	147,0	921,9
			Oct. 21	126,1	148,8	147,1	145,7	—	—	—
After spring wheat on twice-plowed land after sod	C-6	1949	April 20	153,0	94,5	109,5	120,1	145,3	145,4	767,8
			Aug. 17	138,5	123,2	122,8	130,8	150,4	139,9	805,6
			Oct. 28	131,0	111,1	117,0	124,7	—	—	—
Fallow-row crop sequence	C-4	1950	April 21	128,9	96,0	114,5	121,0	133,1	131,0	724,5
			Aug. 21	151,0	125,8	126,9	150,8	145,3	146,5	846,3
			Oct. 30	176,3	153,0	150,6	135,6	—	—	—
After spring wheat on twice-plowed land after sod	C-7	"	April 21	118,2	105,0	120,4	135,0	138,5	137,3	754,4
			Aug. 21	130,9	120,9	131,6	142,1	149,7	156,2	831,4
			Oct. 31	173,3	162,5	147,0	140,6	—	—	—
The same	C-11	1951	April 20	174,1	150,4	129,4	114,8	123,5	130,0	822,0
			July 16	146,1	127,0	117,2	—	—	—	—
			Aug. 28	139,9	136,5	130,7	116,6	125,8	135,3	784,8
			Nov. 3	155,8	135,9	124,2	115,3	—	—	—
Fallow-row crop sequence	C-10	1952	May 9	150,2	118,7	137,7	148,2	147,5	156,5	858,8
			Aug. 16	137,2	128,9	138,2	142,2	144,8	155,2	846,5
			Oct. 24	118,6	120,4	138,7	141,2	—	—	—
After spring wheat on twice-plowed land after sod	C-5	"	April 30	150,0	106,3	111,5	111,3	111,0	106,5	697,2
			Aug. 22	141,7	105,1	115,0	125,0	133,9	136,7	757,4
			Oct. 24	113,6	90,7	101,6	104,5	—	—	—

Note: Comma represents decimal point.

also show that in most cases the spring moisture regime of the soil profile determines whether there will be accumulation during the fallow period. When the spring water contents were deficient, the accumulation of moisture during the fallow period was higher.

The dynamics of soil moisture in black fallow during dry years is shown in Table 3. Moisture did not accumulate in black fallow during dry years. In three cases of the eight observed there were losses of 114-31 mm in the fallow period, and in only one case was there an accumulation during this period amounting to 80 mm (C-6, 1953). This case was typical in that the moisture accumulation by the black fallow occurred in a field where the initial spring moisture accumulation was minimum. With a few exceptions there was no decline in the spring water contents in the deep layers during the fallow period. On the contrary, in most cases the moisture contents of these layers were replenished even in dry years. Where the water table was deep, the moisture contents could be increased by gravity water from the upper horizons. Hence losses in soil moisture during the fallow period with depth of 50-150 cm can be considered conditional.

Thus, analysis of 13 year's data on the moisture regime in black fallow does not justify definite conclusion on the movement of suspended soil moisture.

Soil Moisture in the Fall-Winter Period

We made observations on soil moisture in non-fallow fields in the absence of absorption during the fall-winter periods of 1945-1946 on fall-plowed fields, and in 1946-1947 on fall-plowed fields, once-plowed land after sod and fields of perennial grasses. The fall of 1945 had a large amount of precipitation, which wetted the soil to a depth of 70 cm. At the end of November a severe cold wave occurred, and on some days in November the air temperature reached -25°C. Data on soil-moisture dynamics in fall-plowed land during the fall-winter period of 1945-1946 are given in Table 4.

These data show that the moisture of the soil layer from 0-150 cm increased until

Table 3

Soil moisture in millimeters for dry years

Position of black fallow in crop rotation	Field No.	Year	Date	Depth, cm						
		of observation		0–50	50–100	100–150	150–200	200–250	250–300	0–300
Fallow-row crop sequence	C-3	1943	April 13	178,1	155,0	169,2	170,7	167,0	149,2	989,2
			June 21	147,5	137,8	156,2	164,2	—	—	
			Aug. 6	144,2	132,9	142,6	150,8	155,5	149,1	875,1
			Oct. 25	97,2	135,3	146,2	144,4	—	—	—
After spring wheat on twice-plowed land after sod	C-1	"	April 18	158,9	157,6	137,3	142,9	145,1	139,6	881,4
			June 17	154,6	154,1	148,1	—			
			Aug. 6	147,5	154,2	155,7	144,0	129,0	132,8	863,1
			Oct. 25	109,8	136,9	149,3	136,2	—	—	—
Fallow-row crop sequence	C-1	1946	April 29	172,6	154,0	144,0	154,7	142,0	122,7	890,4
			June 17	143,1	148,8	141,3	154,0	—		
			Aug. 6	131,8	149,6	141,4	148,5	154,7	153,3	879,3
			Sept. 1	155,7	159,9	139,4	146,2	—	—	
After spring wheat on twice-plowed land after sod	C-4	"	April 29	181,4	131,8	116,9	124,3	130,9	137,0	823,3
			June 18	146,3	129,0	118,5	118,7	—		
			Aug. 7	148,5	127,5	127,1	120,7	129,7	138,6	792,1
			Oct. 29	168,7	151,6	138,1	133,7	—	—	—
			May 2	149,2	161,6	157,0	153,8	155,2	152,0	928,8
Fallow-row crop sequence	C-3	1948	June 17	140,9	144,1	149,2	—	—	—	—
			Aug. 26	139,4	155,8	154,6	—	—	—	—
			Sept. 1	153,0	153,5	156,8	146,0	155,0	149,3	913,6
			Oct. 29	156,1	146,4	145,4	141,7	—	—	—
After spring wheat on twice-plowed land after sod	C-10	—	May 5	155,1	150,8	154,1	144,9	140,7	133,6	879,2
			May 15	151,6	151,8	Not det'd.				
			May 28	139,3	145,8					
			June 4	136,3	145,5					
			June 17	150,8	143,1	144,7	—	—	—	—
			July 27	147,0	138,7	156,6	—	—	—	—
			Aug. 25	158,2	141,1	153,9	148,8	138,9	133,2	874,1
			Sept. 17	145,3	142,0					
			Oct. 27	151,6	130,1	153,1	148,3	—	—	—
Fallow-row crop sequence	C-1	1953	April 23	172,0	161,5	133,2	139,4	129,4	139,5	875,0
			Aug. 29	147,0	148,8	120,0	134,7	133,8	135,8	820,2
			Oct. 14	128,4	149,3	122,8	141,4			
After spring wheat on twice-plowed land after sod	C-6	"	April 30	143,9	115,3	103,4	113,9	115,5	112,0	703,9
			Aug. 29	140,3	130,2	115,9	119,3	132,8	144,8	783,3
			Oct. 14	116,6	124,2	112,8	125,2	—	—	—

Note: Comma represents decimal point.

December 13. From January through March it continued to increase in the 0-40 cm layer and declined somewhat in the 80-130 cm layer. The moisture of the 0-50 cm layer greatly exceeded the field capacity (the field capacity of the soil was 25%-28%).

On December 13, 1945, a continuous ice crust covered the surface of the soil. The continued increase in moisture of the upper layers can be explained by movement of moisture in vapor form from the deep layers because of the presence at this time of sharp temperature gradients.

Similar data were obtained in the winter of 1946-47.

The fall of 1946 was dry. Until the arrival of continuous cold weather the moisture in the layer from 0-20 cm was within the field capacity. The data obtained are given in Table 5.

The level of fall and winter soil moisture in 1946-1947 was lower than in 1945-1946. But just as in 1945-1946, the upper layer of fall-plowed land constituting the fallow-row crop sequence of rotation was wet more intensive during the winter than the once-plowed land and the mixed grass land. In the spring, on the other hand, the once-plowed land after

Table 4

Soil moisture in fall-plowed land, % (1945-46)

Depth, cm	Date of observation							
	Nov. 2	Nov. 20	Dec. 13	Jan. 1	Feb. 7	Mar. 5	April 1	April 21
0—10	35,4	39,3	45,9	77,1	92,2	90,8	79,5	35,5
10—20	31,0	35,3	40,3	61,8	68,1	69,2	55,1	34,1
20—30	26,9	31,7	31,0	40,4	34,9	44,1	36,4	42,6
30—40	23,3	25.5	27,9	26,9	26,9	29,2	29,1	25.5
40—50	21,6	23,3	23,1	22,2	23,6	22,8	23,4	22,7
50—60	21,3	22,9	22,3	22,3	22,3	21,6	21,8	22,8
60—70	19,1	22,9	22,0	22.9	21,3	22,2	21,6	22,5
70—80	16,2	20,8	23,2	22,1	20,6	20,6	22,6	21,3
80—90	14,7	19,5	22,7	20,4	18,6	19,8	20,9	23,2
90—100	15,0	18,1	23,1	19,7	19,3	18,0	18,9	19,8
100—110	18,1	18,1	20.6	22,8	19,7	13,2	18,9	19,8
110—120	23,7	20,1	22,3	20,5	20,2	19,6	19,8	21,1
120—130	20,8	21,9	24.2	21,7	22,1	21,9	23,9	22,3
130—140	22,4	23,9	23,9	25,2	24,3	21,1	22.4	22,4
140—150	22,3	24,2	24,5	23,7	25,9	23,0	23,8	23,9

Note: Comma represents decimal point.

Table 5

Soil moisture, % (1946-47)

Depth, cm	Fall-plowed land					Once-plowed land after sod					Mixed grasses			
	Date of observation													
	Nov. 4	Nov. 27	Jan. 24	Mar. 8	April 3	Nov. 4	Nov. 27	Jan. 24	Mar. 8	April 3	Nov. 4	Nov. 27	Jan. 24	April 8
0—10	23,4	53,9	50,9	42,0	38,4	22,8	44,8	51,0	54,7	34,3	23,0	54,0	40,7	25,9
10—20	23,3	34,8	40,4	27,1	37,3	20,7	34,1	29,0	28,5	34,2	21,8	28,6	34,2	26,7
20—30	17,7	22,3	29,3	21,8	34,7	16,5	21,9	17,6	21,2	33,8	15,6	23,3	26,0	25,3
30—40	15,7	16,7	20,4	15,8	32,9	13,8	14,3	17,3	17,5	32,3	13,6	16,0	20,1	23,0
40—50	14,8	13,5	15,6	14,7	27,6	14,1	16,8	16,7	17,0	29,5	13,5	15,2	18,4	18,1
50—60	14,8	13,8	12,9	14,4	25,1	15,0	15,3	14,6	15,5	26,1	13,4	13,2	14,9	13,4
60—70	14,8	12,9	12,6	14,0	16,7	14,2	14,3	14,5	14,7	24,1	13,3	12,2	15,1	13,3
70—80	15,2	13,1	13,2	14,4	14,1	14,8	16,5	15,3	14,4	23,1	13,8	12,9	13,0	14,1
80—90	14,8	13,0	13,3	14,1	14,3	14,0	15,2	16,7	14,5	22,0	13,8	12,9	12,8	13,2
90—100	15,1	12,5	13,6	14,7	14,5	16,0	17,3	17,3	14,5	21,8	13,9	14,0	11,7	13,5
100—110	14,8	14,4	13,4	14,6	16,0	15,9	15,9	16,2	14,6	18,1	14,2	14,8	12,5	13,2
110—120	15,0	13,7	13,6	13,9	15,3	15,0	16,0	15,7	14,8	16,7	13,8	14,6	12,7	13,1
120—130	17,4	15,4	13,7	14,0	17,4	16,2	15,8	15,9	14,6	16,8	14,5	16,9	13,4	13,7
130—140	18,2	13,9	14,7	16,1	18,4	17,3	16,2	16,3	15,4	16,0	14,4	17,5	12,7	14,2
140—150	15,8	14,3	15,2	15,4	16,0	18,0	17,4	15,4	14,9	17,6	17,2	19,6	17,7	15,6

Note: Comma represents decimal point.

sod was moistened to a depth of 110 cm (April 3), and the fall-plowed land to a depth of 60 cm. This was associated with the greater permeability of the once-plowed land for the abundant water in spring than the fall-plowed land of the fallow-row crop sequence.

Thus, our study of the winter dynamics of soil moisture showed that, regardless of the nature of the fall wetting of the soil profile, soil moisture moved out of the lower layers during winter and moistened the upper horizons. In 13 years of observations a similar change in the water regime during summer in black fallow was never observed.

The Moisture Cycle of the Plow Layer

After the disappearance of the snow in 1946, observations were made on moisture variations in two sequences of the crop rotation. The basic observations were made to a depth of 0-100 cm, and in the intervals between them, moisture determinations were made in microlayers of the 0-30 cm plow layer.

Rain fell at the time of the observations in early spring. From April 8-17, a total of 30.7 mm fell. After April 17 a continuous dry period set in, the relative humidity of the air reaching 27%. The soil moisture dynamics in the period from the disappearance of the snow until harrowing may be described as follows (Table 6).

In the fall-plowed land the initial moisture content (April 8) in the layer from 0-50 cm exceeded the field capacity. In the layer from 50-100 cm it was somewhat lower than this constant. In the microlayers of the plow layer during the entire period of observation the moisture content remained high; it decreased in the layer from 30-50 cm; and in the lower layers it remained at about the same level. Consequently, there was a distinct upward flow of soil moisture in very moist fall-plowed land; the descending flow was negligible.

The soil moisture regime in once-plowed land after sod was different. Here the initial high moisture content was found in the layer from 0-10 cm; in the layer from 10-50 cm it exceeded the field capacity somewhat; and in the layer from 50-100 cm it approximated the unavailable moisture. As the soil approached optimium, the moisture of its upper layers decreased and that of the lower layers increased. In contrast to the fall-plowed land, there was a descending flow of water here. Water losses during the period from the disppearance of snow to surface harrowing are indicated by the data in Table 7.

These data show that in fall-plowed land water was lost to evaporation from the 0-50 cm layer. The moisture increase in the layer from 0-10 cm between April 8 and 17 is related to the occurrence of atmospheric precipitation. The lower layers were not replenished by percolation to any significant degree. The daily water losses in fall-plowed land between the disappearance of snow and surface harrowing were higher than the possible losses (according to Meyyer, the possible losses during this period were equal to 2.77 mm per day).

In the once-plowed land after sod, water was lost from the 0-10 cm layer, but in all the other horizons the water contents were replenished. Here the total daily losses to evaporation were less than the possible losses (according to Meyyer).

The same soils were the objects of observations on soil moisture between surface harrowing (April 21) in 1946 and the germination of spring wheat (May 8). This was a period of continuous dry weather. The total soil-moisture losses by layers during this period are given in Table 8.

Table 8 shows that between surface harrowing and the germination moisture was lost from the 0-30 cm layer. In fall-plowed land the moisture content remained almost unchanged below this layer. In once-plowed land after sod, the amount of soil moisture in the layer from 0-50 cm decreased, but in the layer from 50-100 cm the water content was appreciably replenished. This indicates that gravity water passed on to the lower layers. The total and daily losses of soil moisture were lower in the once-plowed land than in the fall-plowed land.

As the moisture content decreased toward the field capacity, the supply of moisture from below also decreased, and moisture was lost only from the plow layer.

The year 1948 was identical to 1946 as regards dryness in spring. In 1948 daily observations were made from May 11-14 on moisture changes in the plow layer: at 1:00 p. m. sunset, and sunrise. The data from these observations are given in Table 9.[1]

The data show that the moisture content of the plow layer (5-30 cm) was higher than the field capacity. During the whole observation period the moisture content of the microlayers of the plow layer gradually decreased. The moisture of the 0-5 cm layer was subject to the greatest variations. As a rule, the moisture content in this soil layer increased between sunset and sunrise. The increase was accompanied by an appreciable decrease in the moisture content of the layers below.

Simultaneously with the moisture determination at sunset, weighed Nekrasov sample holders with soil from the 0-5 cm layer were inserted to the depth of this layer. In the morning, before sunrise, they were isolated from below with a lid, removed, and weighed again. The data obtained are given in Table 10.

The observations show that soil moisture continues to evaporate during the night. Hence the increase in the moisture of the upper microlayers of the plow layer and the decrease in the moisture content of the layers below indicate that it moves toward the surface of the soil. This process was less clearly demonstrated by observations on the moisture content of the plow layer of black fallow from June 24-27, 1948 (Table 11).

The data of Table 11 show that the moisture in the upper part of the plow layer fluctuated in a daily cycle but remained almost unchanged in

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[1] Observations made together with L.M. Zapasnikova.

Table 6

Soil moisture, %

Site of observation	Date of observation	Depth, cm				
		0–5	5–10	10–30	30–50	50–100
Fall-plowed land	8. April	42,9	42,1	52,8	44,0	20,6
	10. "	42,6	45,8	50,0	Not det'd.	
	11. "	36,8	39,2	37,0	" "	"
	17. "	50,1	46,0	38,7	" "	"
	18. "	48,3	45,6	39,2	28,8	22,1
	19. "	37,7	38,2	41,1	—	—
	20. "	34,6	37,3	35,7	28,2	22,0
Once-plowed land after sod	8. "	40,6	40,0	26,9	28,2	15,0
	10. "	37,8	38,3	31,8	Not det'd.	
	13. "	36,0	36,3	34,6	" "	"
	18. "	35,5	35,8	33,2	29,4	16,5
	19. "	30,5	33,9	33,6	Not det'd.	
	20. "	28,6	31,7	31,6	28,0	19,5

Note: Comma represents decimal point.

Table 7

Moisture losses between disappearance of snow and surface harrowing, mm

Site of observation	Observation period (in April)	Depth, cm						Precipitation, mm	Total losses	Daily losses	
		0–5	5–10	10–30	0–30	30–50	50–100			Total	Spring moist. content only
Fall-plowed land	8–17	+6,05	+5,50	–32,40	–20,85	—	—	30,7	—	—	—
	17–20	–8,86	–5,19	– 2,67	–16,72	—	—	—	—	—	—
	8–20	–2,81	+0,31	–35,07	–37,57	–39,60	+12,40	30,7	95,47	7,95	5,4
Once-plowed land aft. sod	8–17	–2,04	–0,70	+16,24	+13,50	—	—	—	—	—	—
	17–20	–2,76	– 1,87	– 3,51	– 8,14	—	—	—	—	—	—
	8–20	–4,80	–2,57	+12,73	+ 5,36	+ 0,40	+11,30	30,7	–13,64	–1,13	–0,7

Note: Comma represents decimal point.

Table 8

Moisture losses, mm

Depth, cm	Fall-plowed land	Once-plowed land after sod
0–5	–13,32	– 9,51
5–10	– 8,93	– 6,40
10–30	–14,35	–21,59
0–30	–36,60	–37,50
30–50	+ 0,76	– 6,40
50–100	+ 0,82	+25,00
0–100	–35,02	–18,90
Daily evaporation	– 1,94	– 1,05

Note: Comma represents decimal point.

the layer from 20-30 cm. Just as in spring, the tendency for the moisture content of the upper microlayers of the plow layer to increase toward sunrise remained throughout the period of observation. But in this case the increased soil moisture did not result from movement from the lower layers; it apparently increased as a result of condensation. This is shown by the data from observations on sample holders inserted into the soil (Table 12).

Soil moisture was high in the fall of 1948. Cold, dry weather began on November 1. Soil-moisture observations were made during the day on November 2-3, in fall-plowed land of the fallow-row crop sequence of crop rotation, under mixed grasses on once-plowed land, and under winter rye. The data obtained are given in Table 13.

In all instances the moisture content of the microlayers of the upper part of the plow layer

Table 9

Soil moisture, %

Depth, cm	May 11		May 12			May 13			May 14
	1:00 p. m.	Sunset	Sunrise	1:00 p. m.	Sunset	Sunrise	1:00 p. m.	Sunset	Sunrise
0—2	7,79	6,81	8,25	6,91	4,35	5,76	6,53	5,42	7,41
2—5	24,11	22,05	23,15	23,00	22,46	23,42	21,11	20,41	21,08
5—10	29,12	29,41	30,18	25,70	28,43	28,00	27,70	27,73	27,10
10—20	29,53	29,11	29,03	28,63	27,38	27,40	27,88	27,56	27,64
20—30	29,67	29,00	28,54	28,45	28,15	27,57	27,60	27,13	27,30

Note: Comma represents decimal point.

Table 10

Moisture loss in a sample holder, %

Replication	May 11-12	May 12-13	May 13-14
I	—0,28	—0,37	—0,65
II	—0,24	—0,33	—0,55
III	—0,26	—0,36	—0,52

Note: Comma represents decimal point.

(0-10 cm) decreased during the day. In the lower layers (20-30 cm) it actually did not change during this time. The moisture contnet of the upper microlayers had risen appreciably in the morning, but there was a corresponding decrease in the lower part of the plow layer. In the fall, when the moisture content of the plow layer was high, movement of the moisture within this layer was clearly noticeable.

Conclusions

1. When the water table is ordinary chernozem is deep, soil moisture in black fallow does not move very much during the summer.

Table 11

Daily moisture content of black fallow, %

Depth, cm	June 24		June 25			June 26			June 27 Sunrise
	1:00 p. m.	Sunset	Sunrise	1:00 p. m.	Sunset	Sunrise	1:00 p. m.	Sunset	
0—2	4,76	5,13	5,90	4,95	4,01	4,91	3,48	3,91	4,52
2—5	7,33	8,40	9,79	6,95	6,77	8,51	7,41	6,14	8,35
5—10	23,63	23,77	23,80	23,34	22,49	23,00	23,73	22,00	22,96
10—20	28,95	28,93	27,97	28,17	28,59	19,25	28,09	28,14	27,59
20—30	29,18	29,40	29,09	29,51	29,88	29,11	29,70	29,80	29,05

Note: Comma represents decimal point.

Table 12

Quantity of sorbed water, grams

Republication	June 24-25	June 25-26	June 26-27
I	+0,06	+0,06	+0,10
II	+0,09	+0,07	+0,06
III	+0,05	+0,04	+0,07

Note: Comma represents decimal point.

2. Regardless of the nature of all moistening, soil moisture under these conditions moves appreciably from the lower to the upper horizons during the winter.

3. In early spring when the moisture level is high (above the field capacity), the soil moisture is most mobile, and there is a distinct ascending flow from the lower microlayers of the plow layer into the upper. In excessively wet fall-plowed land the ascending flow of water is much less distinct than in once-plowed land

Table 13

Soil moisture, %

Depth, cm	Once-plowed land after sod			Fall-plowed land			Winter rye		
	Sept. 2		Sept. 3	Sept. 2		Sept. 3	Sept. 2		Sept. 3
	1:00 p. m.	Evening	Morning	1:00 p. m.	Evening	Morning	1:00 p. m.	Evening	Morning
0—2	31,21	30,26	32,32	30,89	30,02	32,56	36,32	35,46	38,96
2—5	30,61	30,85	32,84	31,11	31,19	33,85	36,42	35,31	36,03
5—10	29,47	29,00	30,35	30,68	30,81	31,00	37,40	36,10	34,81
10—20	28,76	28,75	27,95	31,00	31,08	29,79	33,99	33,52	33,05
20—30	28,45	28,30	28,09	30,80	30,35	28,30	34,00	33,85	33,10

Note: Comma represents decimal point.

after sod. In this period, moisture is lost by evaporation from the 0-50 cm layer in fall-plowed land, but only from the 0-10 cm layer in once-plowed land.

4. In spring and summer, as the level of soil moisture declines, the movement of soil moisture is reduced to such an extent that it is not detected by existing methods. In the absence of absorption by plants the moisture cycle involves only the upper layers of the plow layer.

5. In the fall, depending on the moisture content of the soil, the moisture cycle of the plow layer becomes most active.

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THE SOILS OF GHANA - SEVENTH INTERNATIONAL CONFERENCE OF WEST AFRICAN COUNTRIES (CIAO)

YE. V. LOBOVA, V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR

The Seventh International Conference of West African Countries was held in April, 1959, in Accra, capital of Ghana, to consider the economic and natural resources of Ghana. The author of this article participated in the conference and took several trips through the country.

Ghanian soils are studied in two scientific centers: the university in Legona (Professor Greenland (13) and Professor Ney (15), and the Department of Soil Science Service [directed by the soil scientist Brammer, [4]) located in the town of Kumasi.[1] During the past four or five years the Department has published more than 30 articles and reports (Brammer, Charter, Purnell, Crosby, Radvanskiy [4, 6, 13, 16, 17]) on the genesis, fertility, classification, and geography of soils. Some work has also been done by the Forestry Department (Keay, 10) and the West African Cocoa Institute (Charter, 6). Professors Greenland and Ney have done research on the fertility and biology of soils. A number of reports set forth observations on the utilization of soils under cocoa, coffee, pineapple, rubber, sugar cane, and cassava.

The agronomy department of the university has a research station in Nungva (Director, Dr. J. Phillips) and in Kpong on the plain of Accra. Research is being conducted on animal husbandry, crops of various kinds, irrigation, and methods of conserving soil moisture. A dam has been built in Nungva to increase the water storage.

Another type of agronomic station has been set up in Kade in a tropical forest. Technical and agricultural crops and soil fertility along with the farming practices of the local population are being investigated here. In view of the original materials presented at the conference and the small amount of research in Russian on the tropics, we shall describe in this article some of the general findings of Brammer, Ney, Greenland, Charter, etc. (4), along with some of our first-hand observations.

Ghana is situated between 3° west and 1° east longitude and between 5°—11° north latitude.

Ghana is a hilly country with low mountain ranges lying on the east along the Togo border, in the northern mountainous province of Gambaga, and in the central part of the Kumasi region. The principal river, the Volta, is formed by the junction of the White and Black Volta (about 9°201 north latitude). It intersects the country, emptying into the Gulf of Guinea.

The main watershed is found in the south at 7°30' north latitude from which some of the rivers flow in a northeasterly direction to empty into the Volta, while the remaining rivers (and the majority) flow from northeast to southwest and empty into the Gulf of Guinea — the Bia, Tano, Ankobra, Pra, Avensu, and Densu (the river supplying Accra). The Afram and Volta Rivers (after the junctions of the White and Black Voltas), unlike the other rivers, flow from northwest to southeast due, apparently, to the tectonic structure of their beds. Several rivers overflow their banks during the rainy season.

The soil-forming parent material is largely Paleozoic and represented in the northern part of the country by sandstone (Upper Volta), shale, and argillite (siliceous clay); limestone is rare. A belt of granite and metamorphic sedimentary rock is found in the central and western parts, about 55% and 20% of the area being taken up by phyllite and granite, respectively. Pegmatite and quartzite are also abundant. The topography is mostly hilly with residual outcrops.

In the southeast and east along the right bank of the Volta and Oti River lies the Togo mountain chain; the Veme and Kpandu are the names of the principal ranges. They are composed of arkose, quartzite, quartzitic slate, and phyllites. Volcanic series interstratified with ash and basalt are found to the west of the Kpandu. The Ho-Keta plain situated on the left bank of the Volta in the southeast is characterized by hilly relief and composed, in the north, of quartzite, phyllite, shale, and, in the south, of granite and acid gneiss. The basic rocks play an insignificant role here. Tertiary rocks are widespread in the south and southeast. West of the Ho-Keta plain, between the left bank of the Volta and the Akwipim hills, lies the plain of Accra. A broad belt of basic gneisses runs through the center of the plain with acid gneisses and granitic intrusions emerging along the periphery of the plain. Quartzitic slates and phyllites are encountered in the southwest, loose Tertiary rocks in the south and southeast. The plain of Accra abounds in elevated Paleozoic residual outcrops (Fig. 1).

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[1] Organized in 1948 from the Department of Agronomy.

In terms of vegetation, Ghana is divided into two areas: southern (below the Afram River), characterized by tropical rain forests, and northern, characterized by thorny bushes and forest savannahs. In addition, fairly substantial forests (although of secondary origin) have survived in the Togo mountains and in the north in the region of Gambaga (white Volta). There are treeless areas in the southeastern part of the country on the plains of Accra and Ho-Keta.

In Africa the name savannah is applied to treeless areas of low, medium, or high grass (10). Considerable areas of forest and savannahs are of secondary character owing to the fairly widespread cutting — fire system of agriculture and extensive tribal migration in search of better soil and easier living conditions. A primary tropical forest has tall trees (40-50 m in height) which mature in five years. A secondary forest is characterized by lianas in the undergrowth, the trees attaining a height of 6-7 m in five years. Twenty years are required for a secondary forest to reach maturity. Some tall trees from a primary forest are always to be found in a secondary forest.

A wooded savannah and low tropical forest are situated along the rivers in the northern part of Ghana, the so-called "inner savannah." Dead trees 12 m tall are common in the mountainous area of Gambaga. New vegetation here after burning of the savannah consists of tall, coarse grasses, brushwood, and low trees. These regions have less rain than the southern regions (less than 1000 mm); north of the 8° parallel there is a single rainy season (i. e., tropical, not equatorial type of climate). The northern regions are exposed to the dry Saharan winds or "harmattan," in the vernacular, and thus have a long dry season (about six months). Sandstone, clay slate, and, less commonly, limestone are found in the north. Stony soils predominate in the mountains of the Gambaga region. The red tropical soils formed on sloping piedmonts are better. These soils have a neutral reaction in the upper part of the profile and a weakly acid reaction in the lower part. The broad plains, composed of sandstone and clay shale, are poorly drained with the result that the poor lateritic soil has an excess of surface moisture ("ground water latosolic soil").

The soils of the inner savannah are little cultivated owing to their low fertility caused by the prevalence of sandy laterities and ancient lateritic crusts appearing on the surface. The modern valleys now have developed dark clay soils with carbonate concretions or sodium salinization here and there.

Scrub savannahs with low and medium grasses, occasionally with sparse stands of trees, are common on the plains of Accra and Ho-Keta in the southern and southeastern regions of Ghana. Some 400-600 mm of precipitation, occasionally as much as 1000 mm, fall annually, generally in March-April and in September.

More than 2000 mm of precipitation falls almost all the year around in the far southwest on the watersheds of Tano and Ankobra. There is a single, short dry season. Rain-forest soils of the southwest are strongly leached, acid throughout the entire profile (pH <5); they are yellow in color, belong to the lateritic soils, and are called oxysols. The region of the watersheds of the rivers emptying into the Gulf of Guinea, near the tropical forests of Kumasi-Kibi, has less rain — about 1000 mm a year — and two dry seasons lasting two to four months. The soils in the elevated portions of the relief under these forests is red. They are neutral or weakly acid in the humus horizon and strongly acid below. They are called ochrosols (Brammer, Ney, et al). Yellow tropical soils are developed on gentle slopes and poorly drained locations. This then is the general picture of the natural conditions of Ghana.

The soils of Ghana, from the standpoint of classification, may be divided into the following main groups:

I. Soils of the Lateritic Group Under Evergreen Tropical Rain Forests

1. The yellow tropical soils called oxysols (2, 3, 16) have a sandy texture to a depth of one meter. Further down the yellow sandy horizons give way to a reddish-yellow and yellow blocky horizon containing iron concretions and it readily hardens when exposed to the air. The soil horizons and strongly weathered parent material are generally underlain with solid crystalline rocks or bauxites. The soil reaction is acid throughout the profile. The humus horizon is 20-50 cm thick. The humus content is high — 4% — due to the rich forest litter. The adsorption capacity is 2-5 meq. There are no primary minerals; the clay minerals are gibbsite and kaolinite. The humus horizon contains the basic nutrients from cultivated crops. The soils are friable and readily absorb water. They are not very productive and are suitable for non-demanding crops like rubber and oil palm.

2. The red tropical soils with concretions called ochrosols are bright red, more rarely yellowish-red, because they are formed in a semideciduous tropical forest with a dry season when aeration and ruberfaction of the soils take place simultaneously (the reddening is due to dehydration of the iron hydroxides (12). The uppermost horizons to a depth of one meter are friable clay loam. The humus horizon 20-30 cm thick has a neutral reaction (pH 6-7). The deeper horizons (50-100 cm) are blocky and clayey with a very acid reaction (4-4.5).

3. The ochrosols[2] under savannahs have less humus than do soils under forests (with 0.5-1.5% instead of 4%) and a uniform acid reaction throughout the profile. The uppermost horizons are clay loam to a depth of one meter. The deeper horizons are blocky with concretions. These soils, deprived of the rich forest litter after removal of the trees, are much poorer than soils under forests and

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[2] These soils should be given some generic name.

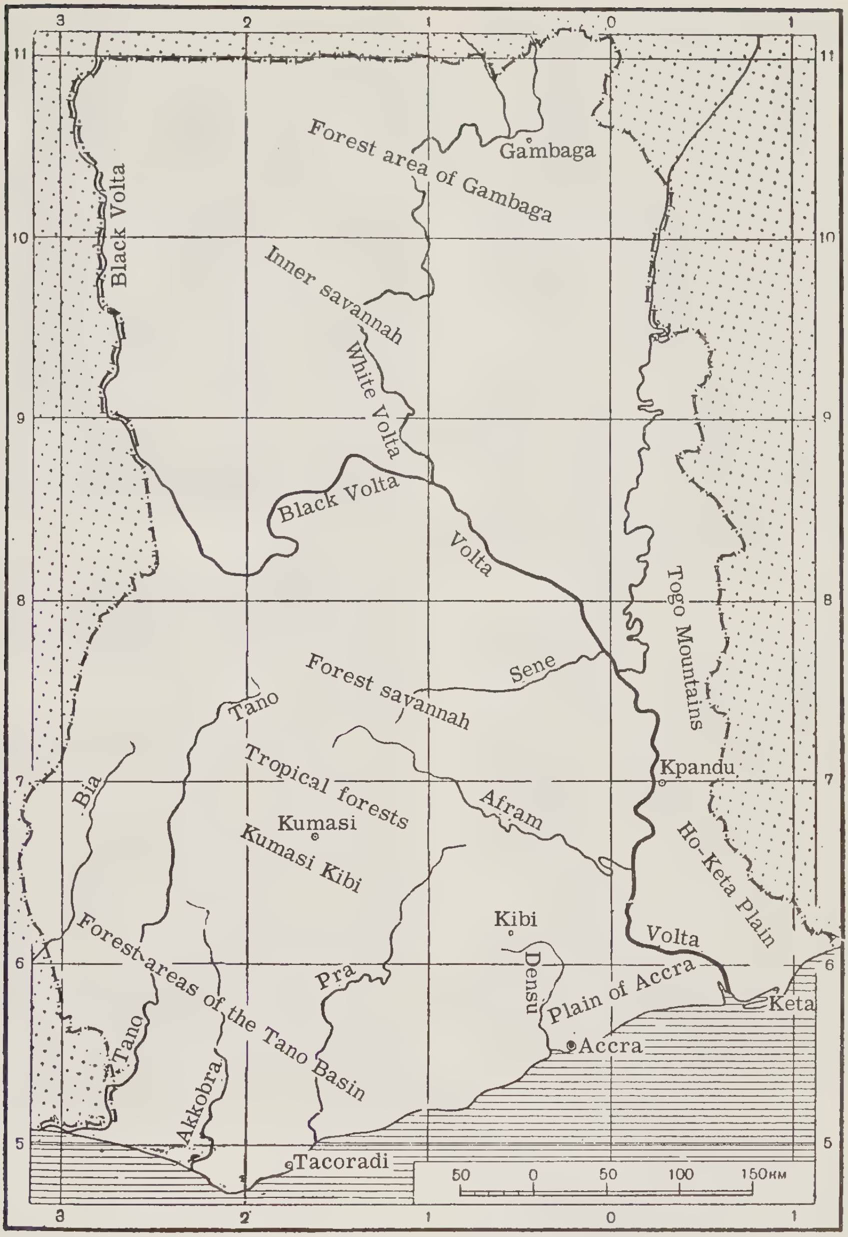

Fig. 1. Schematic map of Ghana

quickly lose their fertility. This process of soil degradation under a secondary savannah has been studied by Berlier, Daben, Leneuf, and Dommergues (5, 7).

4. Red tropical soils under scrub savannahs are found in regions with much less precipitation. They are also less leached, which has an effect on the soil reaction (weakly acid).

5. The dark red (brownish) tropical soils on basic rocks — rubrisols, brunosols — are found under tropical forests or secondary tropical savannahs. They have an alkaline-neutral reaction in the upper part of the profile (pH 7). The concretions in the red clay horizons are usually soft. The soils are rich in primary minerals and best suited for such demanding crops as cocoa.

It would seem that the yellow tropical soils — oxysols — are the most acid and with clay minerals of the gibbsite group, i. e., markedly allitic, are strongly laterітied soils, developed under constantly moist conditions, not aerated, which imparts to them a yellow rather moist conditions, not aerated, which imparts to them a yellow rather than a red color.

Ochrosols are generally more weakly lateritized. Hence they are more clayey with a predominance of clay minerals of the kaolinite group; a small quantity of primary minerals is present. These soils have a different water regime and a period of aeration. The resultant red color comes from dehydration of the iron hydroxydes. Ochrosols are used in Ghana for various crops, including cocoa when they are weakly lateritized. Red tropical soils developed on basic rocks that have not yet substantially weathered are classified with the rubrisols and brunosols (3). These soils have a neutral reaction and are rich in primary minerals, an indication that they are comparatively weakly lateritized. According to the soil scientists of Ghana, the weak lateritization is due to the comparative immaturity of the soils. This is responsible for partial disintegration of the primary rocks and fertility of the soil. Rubrisols and brunosols are the best soils for cocoa.

II. Lateritic Soils With Excessive Moisture

Lateritic soils with excessive surface moisture are formed under tropical forests when the terrain is poorly drained or the rocks are virtually impermeable. The uppermost horizons of these soils are grayish, fine sandy, or clay loams 20-25 cm thick. Underneath is a "ferruginous" shell or concretionary clay loam 70-100 cm thick that hardens when exposed to the air. This is all underlain by impermeable weathered rocks. The soils dry out during the dry season. Ghanians in the northeastern part of the country dig subterranean reservoirs in these soils to store water during the rainy season. The soils have been little worked. They are overgrown with coarse grasses and used as unproductive pasture lands. Lateritic soils with excessive ground moisture are grouped with the podzolized soils. Gleization may well be taking place in them.

III. Black Tropical Soils

This group, according to foreign scientists, includes soils of arid tropical regions characterized by an abundance of montmorillonite clay, dark color, low humus content, high adsorption capacity, and carbonate content. The black tropical soils comprise the regurs, margaritic soils, and the tirs (13).

The black tropical soils of Ghana are found on the plains of Accra and Ho-Keta under scrub and grassy savannahs where 600-800 mm of rain falls and the dry season is long (about six months). These unusual soils swell when moist and become sticky, but shiny when dry, breaking up into large prismatic blocks and forming cracks and the characteristic "gilgai" mesorelief, i. e., mounds separated by crevices one meter deep and 10 cm or more wide. The central part of these soils contains a very compact, almost impermeable blocky and prismoidal-blocky horizon, which causes excessive moisture to accumulate on the surface during the rainy season. The soil reaction is neutral-alkaline. Carbonates appear at 30 cm in the form of pea-sized concretions and extend down to the solid gneisses underlying the clay. The adsorption capacity is 20 meq. Despite the black color, the humus content is low — about 2% (4). Cultivation of these soils includes measures to drain the impermeable horizons, accumulate moisture during the rainy season, and improve the structure (J. Phillips).[3] Black soil fields look like low, wide ridges spaced about two meters apart. Brammer and others attribute the properties of these soils to the fact that they were developed on montmorillonite clays. Determinations of the content of adsorbed cations have shown that there are almost equal amounts of adsorbed calcium and magnesium. It seems to us that black montmorillonite soils should be regarded as a special kind of solonetz soils whose solonetz quality arises from the accumulation of magnesium. A similar "magnesian solonetz quality" is found in the smolnitsas of Albania described by Bogatyrev (1).

Montmorillonite clays (judging by the way they occur) are eluvia formed under the exceptional conditions prevailing in the arid tropics. In addition to those enumerated previously, the following soils, which differ according to the conditions under which they were formed, are found in Ghana:

Gley soils of the depressions, which are soils of the meadow group with ground water close to the surface.

Gray tropical soils, developing on a non-drained maritime plain and acquiring solonetzic characteristics as a result of excessive sodium chloride and sodium sulphate. Vleisols are the soils of flood-plain terraces with water close to the surface under grass and reeds. Lithosols are poorly developed soils on solid rock. Regosols are loose sands with an acid reaction located along the coast. Loose sands with a neutral reaction as a result of carbonates in the bed rock are called regosols carbonatés. The flood water makes the sands suitable for growing the coconut palm which, as is well known, "likes to hold its head in fire but its feet in water" (Table 1).

Conclusions

1. The principal zonal soils of the moist tropics are the yellow and red lateritic soils, i. e., oxysols, continuously moist, and ochrosols, aerated. The former are usually found in depressions and gentle slopes, while the latter are found on hills in well-drained locations. Differences in aeration and resultant rubefaction of the soil are also found in different kinds of tropical forests. The oxysols predominate in the rain forests which have no dry season, while the ochrosols are found in

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[3] Black tropical soils are studied in the stations of Nungva and Kpong.

Table 1

General description and utilization of Ghana soils

Soil	Vegetation	Annual precipitation, mm	Seasonal phenomena	pH	Concretions	Land use and crops
Yellow tropical oxysols, strongly lateritized	Tropical rain forest	2000	Dry season not well defined	$\frac{4-4.5^{a}}{4.5-5}$	Concretions and shells	Rubber, oil palm
Red tropical ochrosols, medium lateritized	Evergreen semi-deciduous tropical-forest	1200 (1700—1500)	Two dry seasons (2 and 4 months)	$\frac{6-7.5}{4.5-5.5}$	Concretions	Average quality cocoa
Red tropical ochrosols with ferruginous concretions	Secondary wooded savannah (high-grass)	1200—700	—	5.6—5.4	Hard concretions	Bananas, pineapple, perhaps cassava, peanuts, oil palm, yams
Weakly lateritized savannah ochroysols	Secondary savannah with dense prickly undergrowth	750—400	Well defined rainy season	$\frac{5-6}{5}$	No data	Corn cassava
Dark-red (brownish) tropical rubrisols rich in bases	Tropical forest (savannah)	No data		7	Very soft concretions	Best cocoa plantings
Ground water latosol — laterite with excessive ground moisture	Secondary tropical forest	1200	Sharp increase in moisture during rainy season	Neutral-strongly acid	Shells	Pasture on unproductive soils
Black tropical, cracked	Scrub and wooded savannah	800—400	Well defined dry season (about 6 months)	6—8	Calcareous concretions	Sugar cane, rice (with irrigation)
Gray tropical, dark solonetzic	Sparse low grasses	300—400	"	Neutral	No data	Pasture ground
Gley soils of depressions	Forest, grasses	No data	Seasonal excess moisture	Acid	"	Rice, sugar cane
Vleisols of flood-plain terraces with surface water level, saline in places	Reeds and grasses	"	"	Alkaline	"	Sugar cane and rubber on more clayey soils, cassava on coarser soils
Regosols, acid, sandy, undeveloped	Bare sands	"	Coastal belt with flood water	Acid	"	Coconut palm
Regosols, neutral with calcareous concretions	" "	No data		$\frac{\text{Neutral}}{\text{alkaline}}$		"

[a] Numerator — upper part of the profile; denominator — lower part of the profile.

semideciduous forests.

Kaolinitic-gibbsitic soils, according to several investigators, are the most mature lateritic soils. Kaolinitic soils are less mature (less lateritized). We think that it is desirable for the nomenclature of lateritic soils to include the degree of lateritization.

2. Soils of the zonal type, very weakly lateritized and rich in primary minerals, are found on basic rock. Brammer and other investigators regard them as immature and as incompletely lateritized. Immature soils in the temperature latitudes are known to reflect to a great extent the nature of the rocks on which they are developed.

3. From our observations in Ghana we consider it necessary to divide the broad group of black tropical soils into two subgroups — hydromorphic and automorphic. The latter in several regions are formed on clay lying over ancient crystalline or igneous rocks and have the character of eluvium. Besides an allitic weathering crust typical of the moist tropics, there appears to be a clayey, montmorillonite weathering crust formed in the dry tropics with high temperatures and prolonged dry season.

General Data on The Nature of the Lateritic Soil Profiles

In the process of lateritic soil formation the soils acquire a sandy texture; they become loose, water-permeable, dry out quickly, and readily take in water. Less lateritized soils are usually more clayey. Ferruginous concretions of different shapes and solid deposits within the profile are usually called "crusts," "shells," or vesicular laterites. Inside the profile these crusts are soft, but they harden on coming to the surface (9, 15, 3, and others).

The question of age of soils is very important in the tropical zone. It can be examined in two ways — duration of the process and occurrence of residual, relict soils. The former is determined from the intensity of lateritization, i.e., the most lateritized are considered the oldest. Weakly lateritized soils (e.g., brunosols) are young, not having reached the typical tropical stage. This comparative analysis of the age of tropical soils can be done more scientifically in Ghana than in our latitudes, because there was no ice age in the tropics so that the dry land was not exposed to the catastrophic action of erosion and accumulation throughout the Quaternary period.

Brammer has found three ancient levels with lateritic crusts in Ghana. The first level is Aya, 600-730 m in altitude. It corresponds to bauxite crusts. These levels are found in the Gambaga area where the most strongly leached soils — podzolic laterites — are developed on bauxites. This phenomenon is most unusual because the present rainfall in Gambaga (1000 mm) is insufficient for such strong leaching and laterite formation. We have been led to conclude that soils of the lateritic profile here are relicts. Besides Gambaga a 600 m level has been found in the Kumasi region, where it is called Aya, and in the mountains of Togo.

Ancient soils and lateritic crusts surviving on the residual outcrops of an old peneplain are encountered in southwest Ghana in the basin of the Tano River (2). They occur here on the Aya level, 720 m.

A second level with ancient soils is found in Gambaga, Kumasi, and on the slopes of Togo. This "Akumadan" level is synchronous with the Tertiary deposit of southwest Ho-Keta and is found at the elevation of 420-200 m.

A third erosion level is found below the second at 10 m. Erosion levels in Ghana are linked to oceanic movements in the Quaternary period.

Drs. Ahn and Nye (2, 16) presented interesting and unusual data in their reports which throw light on the relationship between soils and vegetation. It seems that forest soils remain fertile because of the thick litter and because the very deep roots of the tall tropical trees extract nutrients from disintegrated parent material. The soil exists as long as the forest and its fertility remains steady. When a forest is cleared, even it is done carefully, the litter thins out and the roots no longer reach bedrock. The roots of trees in secondary forests (following renewal) are shallower and do not draw fresh nutrients into the soil-formation process so that the soil gradually becomes infertile. The most valuable crops (cocoa, coffee) do not grow in areas cleared of trees. The main source of nutrition for tropical soils is forest-litter humus. Crops can be grown for many years without fertilizer in the shade of a tropical forest. Savannah soils are quickly ruined if they are not fertilized (5).[4] Savannah grasses contain few nutrients. Fallow under forests is richer in nutrients than that under savannahs owing to the tree roots (16).

Such are the complex problems of soil fertility in the tropical areas of Ghana.

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DISCUSSION

A CONTRIBUTION TO THE CLASSIFICATION OF SOILS

K. P. GORSHENIN, S. M. Kirov Agricultural Institute, Omsk

The resolutions of the Twenty-first Congress of the Communist Party of the Soviet Union include a call for "sharp improvement during the next seven years in utilization of the land as the principal means of production in agriculture." The task of the soil scientists is no small one. It is their responsibility to make a scientific inventory of the land so as to reflect the soil as the basic instrument of production. For, without it there can be no sound organization of the land or planning of technical and other measures.

Now as never before soil scientists are confronted with the responsible problem of classifying soils in such a way as to reveal to the maximum their productive qualities. Unfortunately, the proposals made to date in the Soviet Union cannot be said to meet the requirements. They still have a predominance of features that at times are of little use in solving productivity problems. They tend to be of summary nature designed chiefly to establish geographic patterns in the distribution of soils. This is, of course, an absolutely essential element in classification, but by no means the only one. Pochvovedeniye 1958, Nos. 10 and 12, and 1959, No. 1 published pertinent articles by Ye. N. Ivanova and N. N. Rozov. We have taken exception to some of their proposals, which we shall discuss below.

In the article published in Pochvovedeniye, No. 10, the authors state that they have analyzed the local classifications forwarded to the First Delegates' Congress of Soil Scientists. "Despite the existing diversity of viewpoints," they say, "the majority of scientists have nevertheless adhered to the nomenclature of the State Soil Map and sanction only minor deviations therefrom."

We cannot agree with this because the author's own analysis reveals that the divergences in classification are very substantial, particularly in the case of subdivisions below the group. This is wholly understandable because, first of all, they indicate the desire of local soil scientists to reflect the truly important features and, secondly, lists of soils for the State Soil Map were submitted over ten years ago. And even then the lists elicited many theoretical objections. More recently a good deal has changed and new problems have emerged which require major overhauling of our positions in soil science in general and in soil classification in particular. For example, it is now pretty well agreed that classification should be the basis of soil taxonomy, not lists. This does not mean that lists are no longer necessary. Rather, they should be compiled purely on the basis of scientific classification and, for the most part, by regions.

The second important characteristic of the modern approach to classification involves the definitions of group and subgroup adopted by the Interdepartmental Commission on Soil Classification. They should not be regarded as a refinement of the definitions previously proposed by individual authors, as some soil scientists do. The Commission's definitions of group and subgroup include a basic feature lacking in the earlier definitions, i. e., a productivity feature (measures to increase fertility). This basic feature puts the problem of classification in an entirely new light, but the foregoing authors of articles have ignored it, as shown by their requirements for a classification system (Pochvovedeniye 1958, No. 10): "The system should be based on the idea of development in terms of the evolution both of individual soils and of soil formation as a whole. It should take into account the water regime of the soils and phenomena of hydromorphism," etc. No one can object to these notions, for they are sound and necessary. But where is the basic feature — the productivity properties of soils? It can be said, of course, that the productivity properties emerge from their origin, and in principle this is correct. However, questions relating to origin can be approached with different purposes. For example, one can study the forms in which carbonates are produced. To be sure, this is a genetic characteristic, but no one is likely to regard it as fundamental in soil classification. Other specific characteristics can (and must) be studied, but this would not contribute much to understanding the soil as a basic instrument of production.

To our way of thinking, a study of soil genesis and the patterns of geographical description is not an end in itself, but a means of achieving a correct understanding of soils. During the early history of our science it was studied chiefly as a natural formation. This was a necessary stage in soil science. Such investigations are not outmoded even today, but they have a practical purpose — to acquire a knowledge of the soil as an instrument of production. This must be the leading and controlling factor, the final link, in the classification of soils. Herein lies the fundamental significance of the step taken by the Interdepartmental Commission in establishing basic definitions. The authors of the article apparently do not regard them very highly, because they believe that little of importance has occurred since the lists were compiled for the State Soil Map. Hence, there is no reference to the productive properties of soils in describing the various subdivisions they establish.

Before discussing Ivanova and Rozov's classification proposals, we think it necessary to mention the criteria that should be used in elaborating a classification system:

1. Classification subdivisions of soils should correspond to their productive properties.

2. The properties of soils both as a natural formation and as an instrument of production are directly related to the geographical conditions under which they exist. The classification must reflect these conditions.

3. The classification should be the scientific basis for compiling lists of soils by individual regions, the lists eventually reflecting the cultural condition of the soils.

4. The classification network of groups and subgroups of soils should accord with the definitions adopted by the Interdepartmental Commission (some considerations in connection with subgroups will be detailed below).

We shall speak only of groups and subgroups because we still do not have enough information to justify further subdivisions in the general classification. We believe, therefore, that we should confine ourselves to establishing the main groups and subgroups. Additional subdivisions will best be made locally by soil scientists because, as mentioned previously, most differences of opinion relate to identifications below the subgroup. Even when there will be suitable data, it will scarecely be necessary or desirable to include all the genera and species. It is pertinent here to recall Dokuchayev's works: "When I set up the classes and subdivisions enumerated previously, I had no intention of accounting for the actual range of soils... This is scarcely possible or desirable."

We wish to stress the fact that we make a sharp distinction between two concepts — soil formation group and soil group. The former is the broader term and it may include several soil groups.

On the proposals of Ivanova and Rozov, we regret that the limitations of space prevent us from commenting on all of them.

The Interdepartmental Commission decided on a zonal system of classification and the inclusion therein of provincial subdivisions Pochvovedeniye, 1958, No. 8).

The zonality is reflected in the proposals of Ivanova and Rozov. However, we cannot accept their division of zones. For example, they distinguished a steppe zone and included podzolized and southern chernozem and even chestnut soils. The forest steppe has disappeared, as well as the arid steppe zone. Forest-steppe soils turn up partly in the steppe (podzolized chernozems), partly in the forest zone (gray forest soils). Consequently, the steppe zone is so broad that it has virtually lost its specific quality, particularly from the standpoint of productivity requirements. Moreover, the steppe zone (in the conception of the authors) for some reason no longer has the very important link of solonetzes and solonchaks. The zonal principle, therefore, is inconsistent.

The authors based their geographical subdivisions on the idea of facies but only for the steppe zone, not for the forest zone. It is different to understand the usefulness of facies in soil classification. They seek to justify the division of territory by facies by briefly describing the climatic features. However, there is no need of citing figures to show how great the variety of climatic factors is within each facies both in themselves and with respect to their influence on soil formation. Moreover, the authors themselves note the great variety of climatic conditions within the facies. There is no question, of course, of the uniformity of zonal soils within the facies, especially the central facies. It is sufficient to mention that the entire chernozem belt, except the Black Sea and Trans-Baykal regions, is found in the so-called central facies. Are we supposed to gard, for example, the leached chernozems of the Ukraine, Western Siberia, and the Sayan forest steppe as the same soils, especially from the standpoint of productivity qualities? All these chernozems differ markedly in moisture and heat regimes as well as biological activity. So much then for the usefulness of facies in classification. They constitute a totally unnecessary complication and add nothing concrete to the system. Since they were apparently aware that the division of territory into facies was unsatisfactory and that they had to comply with the decision of the Commission, the authors attempted to divide the steppe zone into provinces. But the text of the article says nothing of provinces. One gets the impression that the authors attach very little significance to this highly important problem. That is why the reader must focus on the provinces.

The problem of provisions, in our opinion, must be critically re-examined. We propose, by way of discussion, the following list of provinces and zones for plains and table lands.

1. For the forest zone: (a) Western European, (b) Eastern European, (c) Western Siberian, (d) Central Siberian, and (e) Eastern Siberian.

2. For the forest-steppe zone: (a) Western European, (b) Eastern European, (c) Western Siberian, (d) Uralic, (e) Altayic, (f) Sayan, (g) Eastern Siberian.

3. For the chernozem-steppe zone: (a) Western European, (b) Cis-Caucasian, (c) Eastern European, (d) Uralic, (e) Western Siberian, (f) Northern Kazakh (low hills), (g) Altayic, (h) Sayan, (i) Eastern Siberian.

4. For the arid steppe zone: (a) Ukrainian, (b) Volga, (c) Kazakh, (d) Sayan, (e) Eastern Siberian. The subdivisions apply only to the USSR.

It is evident from this list of zones that, unlike the authors of the articles, we distinguish forest-steppe, chernozem-steppe, and arid-steppe zones. It seems to us that there should be a separate forest zone too. Our list of provinces, which corresponds to the natural conditions and variety of soils, is broader than the Ivanova and Rozov list.

Let us now examine their classifications. As mentioned previously, we shall deal chiefly with groups and subgroups, occasionally with subdivisions where questions of principles are involved.

In the forest zone the podzols are a zonal soil formation group. These soils, depending on the stage of the process and influence of the ground water, includes several soil groups, especially in relation to moisture. The authors were correct in using this feature as a factor in soil identification. But it is not enough. Among the podzolic-bog soils they distinguish gley and gley-like soils, the former being called sod, the latter humic soils. Can sod soils not be humic and humic soils not be sod? How is gley soil to be distinguished from gley-like soil? What is the justification for the division? It seems to us that the earlier designations in terms of degree of gleyization (weak, strong, etc.) reflect the phenomenon better and are more familiar.

Turning to the Commission's definitions of soil groups, it is easy to see that podzolic and sod-podzolic soils differ in: (a) entry and decomposition of plant residues, (b) character of movement and accumulation (sod-accumulative, eluvial), (c) structure of profile, (d) methods required to improve fertility (technique of cultivation, need of organic and mineral fertilizers, liming, etc.), i.e., all the basic features. It is desirable, therefore, to divide podzolic soils into two groups — podzolic and sod-podzolic. By sod-podzolic soils we mean those in which the sod horizon is well formed.

It is difficult to understand why gray forest soils were placed in the podzolic zone. These are after all forest-steppe zonal soils in direct contact with leached and podzolized chernozems. If gray forest soils are placed in the forest zone (this is permissible), why are they in the forest-steppe zone? Nor can we understand why deeply solonetzic soils turned up among the gray forest (gley) soils. These soils belong to a completely different type of soil formation, possessing distinctive productive qualities and found in the taiga only rarely. The position of the solods is likewise not clear. They are not included among the gray forest soils, and this is correct because they represent another type of soil formation. Yet they are grouped with the gley gray forest soils. If solodized soils are regarded as gray forest soils, they should be included in that group. However, since the solodization has a completely different origin, it would have been more correct to transfer them from the gray forest soils into the solodized group.

The gleization is mentioned for some subgroups of the bog group, but is omitted for others. Are there nongley bog soils?

The chernozem group is subject to much criticism. As a result of the authors' relying on facies, almost all the chernozems appeared in one facies and, consequently, are uniform in productivity. The authors were evidently aware of this, so they distinguished provinces within facies, as we noted previously. It is quite obvious that if the province principle is strictly adhered to, everything will fit into place and the classification of chernozem will become concrete.

The article proposes the separation of typical chernozems whose basic feature is a humus content of 60-75 kg per 1 m². Typical chernozems include: fertile shallow, fertile moderately thick medium in humus thick, low in humus very thick. The authors based their separation on the total amount of humus in a profile and were compelled to combine in a single subgroup chernozems varying greatly in genetic and productive features. It is difficult to determine what kind of problems this procedure was aimed at solving. There is hardly any need to prove that it is not the total humus content but its distribution through the profile that is the most important feature. The distribution of humus through the profile reflects the distribution of the root system, which is a basic factor in soil formation. This distribution of the root system, which is a basic factor in soil formation. This distribution also has productivity implications. It is really possible to group fertile shallow and low humus very thick chernozems together? In Siberia, for example, podzolized and leached chernozems are very often fertile. What is the subgroup to which Siberian chernozems belong, following the classification suggested by the authors? One cannot but note that the typical term for chernozems is subgroup, but it is a generic feature for other groups. We feel that the term "typical" as used by the authors is not very apt. We shall return to this question a little later.

The authors distinguish mycelium-like chernozems. However, it is a well-known fact that mycelium is found in many other chernozems than in the Black Sea region. It should be remembered that the presence of carbonates is by the usual definition a genetic rather than a subgroup characteristic. Separation of a mycelial chernozem subgroup is so unrelated to genetic, let alone productivity features, that there is no need to show that this subdivision is meaningless. By the same token, why not distinguish, for example, the pocket-like chernozems of the Tulun-Irkutsk forest steppe as a subgroup, especially since this characteristic undoubtedly has productivity significance? These chernozems will be identified, to be sure, in the regional lists, but as a provincial variety, not as a subgroup. The Black Sea mycelium-like chernozems too are a provincial variety.

Incidentally, the Commission has correctly included provincialism among the subgroups. The provinces obviously have to include all the chernozem subgroups in their structure as well as the other zonal soils. One province may have several subgroups, another only one, depending on the number of subzones. With the principle adopted by the authors for subdividing the chernozems, the external unity of the principle is lost. We find in their list of subgroups: leached, ordinary, southern, and, along with these genetically productive subgroups, weakly leached Black Sea (mycelium-calcareous), ordinary leached East Asian, and others, i. e., subgroups with completely different characteristics. In their diagram the authors were compelled to set out for each province all the chernozem subgroups, which they have done correctly.[1]

We do not propose to discuss the genera of soils in their entirety. But we do want to call attention to the group of solonetzic chernozems. It is quite sound, in our view, to distinguish these chernozems in two cases: (a) when the chernozems are developed on saline parent material, and (b) when solonetzization is a zonal characteristic (southern chernozems). However, the degree of solonetzization must be clearly noted in both cases. The article states that solonetzic chernozems have at least 5% exchangeable sodium, but there is no mention of the upper limit. In view of this indefiniteness, some soil scientists interpret solonetzic chernozems too broadly, assigning to them all dark-humus soils even when they contain 15% or more exchangeable sodium, provided only that there are no columnar structure. This obscures the productivity evaluation of soils. Hence a more precise definition of solonetzic chernozems is particularly necessary. There is the further question of where to assign soils with a 10-15% or more exchangeable sodium content, but lacking in columnar structure. The authors unfortunately do not mention this at all. We stress this fact because the absence of saline soils from the classification give it a fragmentary rather than zonal character.

Once again we suggest dividing the chernozem group into two: (1) forest-steppe chernozems — leached, podzolized, and, in part, ordinary — and (2) steppe chernozems — southern and, in part, ordinary. We say "in part" because although the ordinary chernozems occur mainly in steppes, they are occasionally found in forest steppes as well. Our reason for this division of the chernozems is based on geographical consideration and the Commission's definitions of the group. An analysis of the chernozems from the standpoint of the definitions adopted clearly shows that the differences, genetic and productivity, between the forest-steppe and steppe chernozems fully justify the setting up of two groups.

In discussing our proposal to the Commission, some raised objections on the grounds that the division was not in accord with Dokuchayev's conception of chernozems. These objections, in our opinion, are not valid. The fact is Dokuchayev failed to mention many other soils that have now been identified. Moreover, his division of the chernozems is quite different from the modern division. Are we to be deprived of the right to introduce subdivisions, well supported by factual material, solely because there is no mention of them in Dokuchayev's writings? We are quite aware of the value of tradition, but we also remember the words of Lenin: "To preserve our ideological inheritance does not mean that we must restrict ourselves to it."

Separation of the meadow-chernozem group is perplexing both from the standpoint of the usual definition of a group and from the standpoint of productivity features. Where indeed is there a unity of migration and accumulation of matter if the group includes podzolized, solonetz, solonchak, and other soils, i. e., soils whose processes of migration are exactly opposite in direction and by its nature? An analysis of the group shows that it consists of subgroups, each of which is a deviation from the group rather than a part of it. The group also includes the so-called typical meadow-chernozem soils which, according to the soil map issued by the V. V. Dokuchayev Soil Institute AS USSR, are nothing but watershed chernozems as understood by Siberian soil scientists. The only reason for placing them in the meadow-chernozem group is that the water table is about five meters deep. Aside from the fact that this depth varies considerably from year to year and during a single year and that it is impossible to determine in an ordinary soil investigation, such a ground water level has absolutely no effect on the properties of chernozems. Moreover, these soils are always found in comparatively elevated areas so that there is no accumulation of surface water whatever.

Thus, the meadow-chernozem soils are a collective and mixed group which cannot be justified so that, as formulated by Ivanova and Rozov, it ought to be abandoned. Separating them on the soil map compiled by the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR gives an erroneous impression of the soil in the Western Siberian lowland as far as productivity considerations are concerned. This "group" is farfetched and cannot be supported with factual data.

Ivanova and Rozov have identified meadow and meadow-like soil subgroups solely on the basis that the former have ground water at a depth of 5-6 m, while the latter have ground water at a depth of 3-5 m. This is so transient a phenomenon and so difficult to determine as to be completely meaningless. It is a well-known fact that the water table commonly varies within a range of three meters, particularly in Siberia. Why, then, place in this subgroup soils whose water depth may be at four meters one year and at six meters another? Soil scientists engaged in large-scale surveys are well aware that identifying subgroups on the basis of water depth is a source of great difficulty and confusion. We are in favor of separating new groups and subgroups, but they must be justified. We have no objection to a meadow-chernozem group as long as the components reflect the unity of the group. The solonetzic- and saline soils included by the authors in the meadow-chernozem group should be classified with more appropriate groups. The same remarks hold true in principle for the subgroups of chestnut soils as for the chernozems (mycelium-like leached, etc.). Some confusion in the division into genera arises from such names as noncalcareous chestnut soils. It is hard to conceive of arid steppe soils without carbonates. They probably are not chestnut soils. It is likewise not clear why this was applied to soils called residually calcareous solodized soils. What is residual here — the presence of carbonates or solodization? Nor do we understand what is meant by residual solonetzic chestnut soils, because the actual chestnut process is zonally solonetzic (except those which are texturally coarse and strongly calcareous) so that there is scarcely any residual process worth mentioning. Is it possible that the authors have in mind soils that have passed the stage of solonetzization and are now in the stage of solodization-sod formation?

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[1] Pochvovedeniye, 1958, No. 12, p. 1354 (Transation).

We have many other observations on the classification of Ivanova and Rozov, but space does not permit us to make more than a few general remarks. The question of typical soils (typical chernozems, typical podzols, etc.) is important. At one time we used this term of Flerov for chernozems. By typical chernozems we understood was meant those soils in which the mineral part remained constant throughout the profile and unaffected by the process of soil formation. Later a number of authors interpreted the concept in such different ways that we were obligated to give up the word as far as chernozems are concerned.

According to Ivanova and Rozanov, there are typical soils in all the groups, but it is far from clear what is meant by these soils. In any event the theoretical justification for applying the term varies from soil to soil. For example, typical chernozems are identified by the amount of humus, meadow-chernozems by carbonates in the humus layer and the absence of eluvium, etc. There can, of course, be no unity in principle for the different kinds of soil formation, with the result that there is considerable room for subjectivism and eventual confusion. Typical solonchaks are identified. But what are they? And doesn't the very word "typical" sound strange when used for a natural formation? Does it mean that the other soils in the group are not typical? Why, for example, are chernozems with maximum humus content typical when they are not even predominant in the chernozem group? What are they typical of, if they are not even typical of themselves (e.g., fertile shallow, low in humus very thick, etc)? Finally, let us recall once again that the term "typical" is applied to genera in some groups, but to subgroups in others. Since the term has no theoretical rationale and, moreover, serves no useful purpose, it should be eliminated from the classification lexicon.

Another general observation concerns the particle-size analysis of parent material in the definitions adopted is classified by generic, i.e., insignificant third degree index. It seems to us that the question of particle-size analysis of soil should be re-examined. Everyone is aware of the importance of texture in soil formation and in agriculture (time of planting, time of ripening of crops, fertilizer requirements, methods of cultivation, etc.). That is why more stress should be placed on texture in soil classification. Ivanova and Rozov's proposals should be reviewed with this and the points previously made in mind. A sound and efficient classification can be worked out only if reflection therein of the practical properties of soils is a guiding principle. However elegant the system, it will be abstract and unacceptable unless it takes cognizance of the productivity properties of soils. Any classification must be based on recognition of the special position occupied by soil science among the disciplines engaged in studying natural formations.

It is peculiarity of our science that it is concerned with natural objects and the processes by which they are formed while serving as a theoretical starting point for correct utilization of these natural objects by agriculture. This accounts for the special approach that must be followed in classifying soils.

In conclusion, I cannot but observe that the commission on classification is proceeding too slowly and lagging in activity. Many large-scale soil surveys now in process lack control and unified direction. This naturally creates exceptional difficulties in making generalizations of all kinds and is conducive to subjective interpretation of the materials collected.

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SOME PRINCIPLES IN CLASSIFYING ANTHROPOGENIC SOILS

B. V. NADEZHDIN, Eastern Siberian Branch, Academy ot Sciences, USSR

During the discussion of problems in soil classification, as set forth in recent years on the pages of Pochvovedeniye, comparatively little attention has been paid to soils modified as a result of man's activity. There is no doubt that a study of "cultivated" soils and a determination of the principles governing their classification constitute an important but scarcely investigated problem in modern soil science.

All the scientists concerned concede that the process of soil formation assumes a wholly different character and direction as a result of man's activity. This idea has been clearly formulated by Gerasimov (6) who notes that the genetic properties of soil are formed under certain conditions and that they are radically transformed when the conditions change. Agricultural practices profoundly transform, weaken, or destroy the soil's original genetic properties. At the same time new and hitherto lacking properties come into being. An apparently logical conclusion is that cultivated soils should be treated for classification purposes as independent units, inclusive of groups. However, Gerasimov does not draw this conclusion, suggesting merely that a special category of "cultivated variants" should be set up. Ivanova (12) came more or less to the same conclusion as Gerasimov in regard to the position of agricultural soils in a general classification. She admits that "cultivation brings into play some powerful new factors capable of imparting new properties that do not appear when the soil develops in its natural environment" (p. 74). Nevertheless, "one must not contrast virgin soils too hsarply with soils changed by cultivation because the latter complicates and changes them rather than eliminating the effect of many fundamental natural factors" (p. 74). Ivanova therefore suggests retaining the division of cultivated soils into groups and subgroups determined by their natural properties.

These, then, are the conclusions to which modern specialists have come in regard to the position of soils changed by man in the general system of soil classification.

Let us consider now some of the ideas set forth in the special studies on cultivated soils.

According to Blagovidov (1, 2), as podzolic soils are cultivated their genetic characteristics are levelled out and they become increasingly resistant to the degradation of fertility. Continuous cultivation makes different groups of soils similar but not identical in properties. Initially different zonal groups pass through a common stage of soil formation and then, under the influence of cultivation, come to resemble one another, but they are not transformed into a single group. Blagovidov formulated the concept of genetic groups of cultivated soils. He classified cultivated podzols as "cultivated-accumulative." He and other investigators have suggested identifying cultivated soils as independent groups and subgroups.

M. A. Orlov (23) advocated separating cultivated soil groups specific to each zone. He felt that "plowed" soils ought to be set up in a special section or stage — "anthropogenic" following the "biogeogenic" and "geogenic" stages. He applied this notion solely to the irrigated soils of Central Asia. Smirnov (27) too believed that cultivated soils should be included in a general classification as a group (by zones). Further division into smaller taxonomic units would be made depending on the original natural soil, degree and kind of cultivation. According to Garkusha (3, 4, 5), the development and evolution of cultivated soils is determined largely by the agricultural practices employed. Sod-podzolic soils gradually lose their natural properties, the speed of the process varying with management practices and natural conditions. In all cases, however, cultivation improves the soil and increases its effective fertility. The original natural soil merely serves as parent material on which the new cultural process of soil formation develops.

In the productivity-genetic classification proposed by Garkusha the genesis of cultivated soils is represented only in connection with increased fertility of natural soils from planned agricultural methods, but the substance of the changes in their genetic properties is not shown. Garkusha contradicts himself when he terms the cultivated state the modern stage in soil formation because he goes on to call soils changed by man "cultivated soils of the sod-podzolic group."

Karpinskiy (14) maintains the arable soils are characterized by a specific series of processes different from those affecting virgin soils.

At the same time "the soil-forming process of arable soil includes several processes similar to those characterizing the soil-forming process of natural soil" (p. 61), e. g., the processes of synthesis and decomposition of organic matter and the biological cycle of nitrogen and ash elements. Karpinskiy thinks that soil varieties should be distinguished by degree of cultivation.

V. A. Dolotov (8), critically examining the main studies on classification of cultivated soils, found that several investigators had abandoned Dokuchayev's concept of the soil as an independent natural body. This is manifested chiefly in: (1) considering virgin soil not as a natural body with an historical past, but as a parent material transformed by a variety of agricultural practices into fertile soil; (2) raising "site quality" indices to the level of genetic principles; (3) contrasting cultivated soils with natural soils and, accordingly, breaking up the evolution of soils into two unrelated stages — natural and cultivated.

Dolotov regards the cultivated period of soil formation in the sod-podzolic zone as a modified sod process. As for the place of cultivated soils in a general classification, Dolotov believes that cultivated and natural soils can be distinguished only below the group or even subgroup category.

Before setting forth our own views, we should like to discuss terminology.

When man intervenes in natural processes, he invariably changes to some extent the direction and nature of soil formation. However, it must be admitted that this intervention does not always result in improving the soil or increasing its fertility. The usual word to designate soils modified by man, "cultivated," does not necessarily reflect the true situation. The word should be restricted only to those cases where there actually is improvement and not deterioration of the soil. We believe that "anthropogenic soils" is a more useful term, for it embraces all soils worked by man regardless of whether the result is to a better or to a poorer side.

Let us now consider the extent to which man's activity may change the direction of soil formation in the main natural zones of the Soviet Union.

The forest zone, which makes up a large part of USSR territory, has heterogeneous soils that have not been studied in equal detail. It can now be said with some assurance that the current idea that soils of the podzolic group predominate within the forest zone is incorrect.

The most investigated part of the forest zone is the western area where the predominance of podzolic soils has been fairly well established and where most of the old forest soils have been placed under cultivation. Soil formation changes from the moment a forest is cut, if only partially. Even thinning out of the trees as a result of fire or selective felling changes the varieties of trees and undergrowth. Then there is rapid development of the sod process, i. e., a new subgroup of soils may be formed — sod-podzolic instead of the purely podzolic and sometimes (with high water table) podzolic-gley, i. e., another soil group according to the modern classification.

When a forest is clearcut and becomes covered with grass (which may well happen if the area is used for hay or as a pasture), marked changes take place in the hydrothermal regime of the soil and in the nature of the plant residues. Podzolization comes to a complete halt with the formation of meadow or bog soil (if the water table is close to the surface).

Thus, the changes in the vegetation brought about by man lead to the formation of a new soil subgroup or even group.

Dolotov (8) fairly observed that it was not the original taiga soils that were cultivated, but the soils that had in varying degree been changed by man, i. e., they had passed through the stage of formation under sparse forests with altered composition and under meadows or under one of these formations. Soils with a more or less developed sod process and with diminishing or wholly lacking podzol formation are often plowed.

As soon as soil is plowed, the influence of man is sharply intensified. The "cultivated" period of soil formation is usually thought to begin at that time. The period can properly be called "cultivated" if the farming methods promote restoration of the nutrients removed every year from the soil with the harvest and raise the fertility of the arable soil over that of the "pre-cultivated" period.

We have discussed elsewhere (10, 11) the transformation of podzols in the "cultivated" period of soil formation. In our opinion, there is no difference in principle between the process taking place in the soils of fields and meadows in the forest zone, i. e., we regard the transformation of podzolic soils caused by cultivation as a manifestation of the sod process. However, each situation varies in details. This has led us to identify plowed soils and meadow soils of the podzol zone as two separate groups.

For these reasons we cannot assign soils changed by man to the podzolic group. At the same time, as we have already observed (10), the signs of past "natural" soil formation survive to some extent, disappearing entirely only in meadow soils. This is frequently due to the effect of herbaceous vegetation and to the composition of the soil-forming parent material and ground water. We therefore include meadow soils in the sod-meadow group and soils under plowland in the sod-anthropogenic group without calling them "cultivated" soils for the considerations mentioned previously. At least two subgroups must be distinguished within the sod anthropogenic group: 1) residual podzolic, and 2) crypto-podzolized. The first includes soils with pronounced residual signs of podzolization showing up both in the morphology and in the chemistry (acid reaction, loss of exchangeable bases, etc.). The second group includes soils where the residual morphological signs of podzolization are hidden, but analysis discloses certain chemical properes testifying to the fact that they had once been odzolized. There may even be a third sub- roup — sod-residual podzolic-gley — which we nce proposed (10).

In elaborating their systems of anthropo- enic soils, investigators have always used the egree of cultivation as a classification fea- re. Moreover, it has often been thought that aising the level of cultivation results in weak- ning the natural genetic properties of the soil). We cited the example of Kaliningrad Oblast' oils to show that this need not always happen 0). We discovered that soils with clearly pro- ounced signs of past podzol formation, which re helpful in determining both the subgroup nd species to which they belonged in the "pre- ltivated" period of their development, fre- uently turned out to be distinctly improved in rms of productivity qualities. On the other and, some of the soils without these signs were nly very slightly cultivated. It seems to us at, given the present state of our knowledge, xtent of cultivation should not be included in a enetic classification. This feature is appropri- te in connection with soil site quality.

Our observations up to this point apply ainly to the western part of the forest zone f European USSR, the soil of which has been lly treated in the literature.

As we move from west to east, we find a radual change in the conditions of soil forma- on. The climate becomes increasingly con- nental, and the composition and properties of e soil-forming parent material as well as the ature of the vegetation change.

Podzol formation weakens perceptibly in the astern part of European USSR, according to fimtseva (32), and humus accumulation stead- y intensifies as the humus becomes heavily aturated with calcium. The transformation f soils under the influence of the sod process ncluding, too, the effect of cultivation) pro- eeds in the direction of steppe formation (11).

The most continental part of the forest one — Central Siberia — differs sharply in soil rmation from the western part of the zone. odzol formation is not inhibited by drought, ermafrost, and prolonged seasonal frozen round, and predominance of soil-forming arent material that is rich in bases, frequent- calcareous and saline. Within the broad retches of Central Siberia soils of the pod- olic group are not too common and they have eir own peculiarities. The adaptation of odzolic soils to coarsely textured soil-form- g parent material extremely poor in bases s been noted. Most of the land is covered ith unusual sod-forest soils that do not belong the podzolic group. Forest soils trans- rmed by man also develop quite differently om those in the western part of the forest one. Clearcutting of a forest not only changes e vegetation, but also substantially modifies e microclimate. On open treeless areas the il is more exposed to fluctuations in tem- erature which are somewhat mitigated under rests. At the same time the permafrost be- omes degraded (if it was present under for- ts), or the period of seasonal frozen ground shortened. This naturally has a strong effect on the water and salt regimes of the soil.

Our observations show that transformation of the large area of Central Siberian sod-calcareous soils after cutting the forests assumes the nature of a steppe accompanied by solonetzization (19). This type of transformation is evidently a regular phenomenon, at least in the southern part of Central Siberia.

Let us now consider the anthropogenic transformation of soils in different natural zones.

The transformation of gray forest soils after cutting the forests and subsequent cultivation has been thoroughly studied. The resultant changes have been discussed by a number of authors (16, 24, 30, 33). Regraded soils exhibit higher upper boundaries of the carbonate horizon and, contain organic matter saturated with calcium along with decreased acidity. Regraded gray forest soils are shown with a special symbol in the legend of the State Soil Map of the USSR, 1:1,000,000 scale.

The modification of vegetation in the forest-steppe zone is associated, of course, with changes in the water and salt regimes of the soil, although they are somewhat different in character and not so sharp as in the forest zone. These changes in the European part of the Soviet Union tend to make the gray soils resemble the chernozems, and further to the east, e. g., in Central Siberia, they become steppe-like. In any case, as a result of cultivation, new subgroups and possibly even a new group of gray forest soils are formed. It will be noted that applying the term "gray forest" to these soils even with the addition of "regraded" is not very apt. Are we entitled to call "forest" those soils on which there is no forest growth or on which there may have been none for a long them? "Gray anthropogenic soils" seems to be the more appropriate term to our way of thinking.

Man affects chernozems in two main ways: a) by farming and b) by planting trees.

The vast majority of chernozems have been cultivated for centuries. Small areas of virgin chernozems survive only here and there is forest preserves and in the east (Central Siberia, Trans-Baykal) where they possess unusual properties and have been scarcely studied. Hence, it is very difficult to compare virgin and cultivated chernozems in identical physicogeographic conditions. The changes undergone by chernozems as a result of agriculture are much less marked than those characteristic of podzolic soils (9). This is quite understandable, because bringing chernozems under cultivation does little to change the nature of the vegetation and water regime. The nutrient regime obviously undergoes some transformation, since almost none of the nutrients have been replenished during the many years of cultivation. It is a well-known fact that fertilizers are still sparingly used on chernozems.

While making a comparative study of virgin and plowed Azov Sea chernozems, Karnaukhov (13) found that long cultivated chernozems showed a decrease in humus and nitrogen content, deterioration of structure, and reduced water stability. Similar changes were noted by Lazarev (16) on northern forest-steppe plowed chernozems.

The changes in chernozem brought about by forest plantations, even if the area covered is small, are worth studying. It has been demonstrated that such chernozems in the forest steppe of European USSR and Western Siberia have a lower depth of effervescence, less exchangeable bases and humus, and increased acidity (7, 28), i. e., they exhibit signs of degradation. Steppe chernozems (ordinary and southern), on the other hand, have an accumulation of humus saturated with calcium and greater total content of organic matter and exchangeable bases (17, 18, 29, 31). These are indications of resumption of the sod process.

Thus, research data show that cultivation of chernozem soils merely changes some of their functional properties. The main genetic properties which determine the group or even subgroup to which they belong remain substantially unaltered. That is why anthropogenic chernozems in a general classification may be identified as species or possibly as intermediate taxonomic units between the subgroup and species. In any case, a solution of the problem requires a detailed investigation of soil formation in the chernozem zone.

An important factor in the transformation of desert soils is secondary salinization caused both by the influx of large quantities of salts with irrigation water and by rising mineralized ground water during the hot summer (15). The result is not only an increase in the salt content of naturally saline soils but, also an accumulation of salts in soils that were hitherto not naturally saline.

A. N. Rozanov (25) found that irrigation of sierozems generally causes gleying from intensification of the weathering processes and dispersion of aggregates. An increase in the content of colloids increases the adsorption capacity. There is a simultaneous change in the composition of adsorbed cations. The relative amount of magnesium increases sharply, that of sodium less so, while the relative calcium content decreases. The amount of humus and nitrogen likewise decreases. Accoring to Rozanov (25), all these phenomena are also typical of natural sierozem formation, differing from the latter only quantitatively. Rozanov, therefore, could not agree with Orlov (20, 21, 22) who thought that a new type of cultivated-oasis soil formation arises with the start of irrigation. Rozanov subsequently acknowledged the need for setting up a special subgroup of irrigated sierozems (26).

Regarding long irrigated oasis soils, Rozanov (26), like Orlov (20, 21, 22, 23), concluded that it would be useful to place them in a special group subdivided into two subgroups: a) long irrigated meadow-sierozem soils with more pornounced signs of sierozem formation and at the same time less subjected to secondary salinization, and b) long irrigated sierozem-meadow soils in which meadow-like features can be more clearly discerned and which are solonchak-like solonchak, and sometimes solonetzic.

Summarizing the foregoing considerations, we wish to point out that despite the comparatively slight attention accorded modern soil formation to cultivation it is now possible to formulate certain principles for classifying and systematizing anthropogenic soils by natural zones.

In the western part of the forest zone, anthropogenic transformation of podzolic soils is proceeding toward the development of a sod process along with weakening and, ultimately, complete termination of podzol formation. Moreover, this transformation is caused both by agricultural practices and by the change in vegetation entailing sharp modifications in the hydrothermal regime of the soils as well as in the nature of the decomposition and synthesis of the organic and mineral parts of the soils.

Moving eastwards in the forest zone, there is a gradual change in the character of the natural soils and where the climate is markedly continental (Central Siberia), podzolization is no longer the principal process in creating forest soils. Anthropogenic transformation of soils to the east increasingly acquires the character of steppe formation. This justifies our belief that the transformation of soils attributable to cultivation in the forest zone lea to the creation of several new soil groups and subgroups parallel to the series of natural soils.

In the forest-steppe zone man-caused modifications tend to make the gray forest soils resemble chernozems. There is increasing steppe formation from west to east, just as in the forest zone. The transformation of these soils, in our opinion, results in the creation of new subgroups and, possibly, even groups.

Cultivation of chernozems both in the forest-steppe and in the steppe zones brings about changes in functional properties, whereas the basic genetic properties remain more or less as they were. That is why it is possible to distinguish anthropogenic species or taxonomic units intermediate between the species and subgroup.

In the sierozem zone irrigation causes an increase in meadow formation and, in many cases, in secondary salinization, i. e., there is a considerable change in the genetic properties of irrigated soils. The usefulness of setting up irrigated soils as an independent subgroup or even groups can no longer be challenged.

These, then, are some of the theoretical considerations which, to our way of thinking, might serve as a basis for classifying anthropogenic soils in different natural zones. It is obvious that refinement of the system must await thorough experimental research.

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METHODS

THE PRESENCE OF EXCHANGEABLE ALUMINUM IN SOILS

A. V. SOKOLOV, Dolgoprudnaya Agricultural Chemical Station, Scientific Institute of Fertilizers, Insecticides and Fungicides

The exchangeable acidity of the soil is determined by titration, with a base, of salt extract (1 N KCl) of the soil. As early as 1904, Veitch (9) noted that the acidity of salt extracts of soils is created by the presence therein of aluminum. After him various authors in numerous papers studied the question of whether exchangeable aluminum exists in the soil. The presence of aluminum in the salt extract of soil can be explained by a secondary reaction occurring at the time the extract is made. A cation of a neutral salt displaces exchangeable hydrogen from the soil, and the acid formed breaks down aluminum silicate or other aluminum compounds, so that they appear in the solution. According to this thesis, the exchangeable acidity of the soil is determined only by the presence therein of exchangeable hydrogen, and not of exchangeable aluminum or other mobile compounds thereof which enter the salt extract directly (2).

But some phenomena observed in experiments cannot be satisfactorily explained on this basis. The exchangeable acidity of some soils — sod-podzolic soils and red earths — is equivalent to the aluminum content in their salt extracts, while in extracts of other soils — peat soils — this does not occur (4, 5). Treatment of the soil with weak solutions of HCl or 1 N KCl with a minute quantity of HCl gives results that differ from treatment of the soil with a 1 N solution of KCl (4). Treatment of podzolic soils and red earths with NaF solution results in alkalization of the solution, and treatment of peat soils with the same solution leads to acidification of the solution. This is associated with a different content of exchangeable aluminum and hydrogen in these soils, since the aluminum upon the addition of NaF forms the insoluble compound cryolite, Na_3AlF_6, and the excess Na^+ in the solution causes the alkaline reaction (6).

The retrogradation in sod-podzolic and red earths soils of water-soluble phosphates and the continuous residual effect of ground rock phosphate is easier to explain on the basis of the presence in the soil of exchangeable aluminum or other active forms of it than on the basis of the assumption that the exchangeable acidity of the soil is determined by the presence of exchangeable hydrogen (7).

Chernov, in his thorough monograph (8), gives the results of numerous experiments on the interaction between the soil and the salt extract, indicating the presence in the soil of exchangeable aluminum. But in the review pape of Askinazi, Karpinskiy, and Remezov (1) it is noted that so far there is no direct evidence that the aluminum entering the salt extract from the soil can be considered as the same sort of exchangeable cation as calcium, magnesium, potassium, and the others.

At the present time, to study this problem, we can use the interaction of the soil with cationite. The movement of Al^- or the H-ion from the soil to the cationite occurs without the secondary reaction of solution of soil aluminum compounds by the acid formed at the time the salt extract is made.

Each ion was transferred from cationite to clay minerals by passing a soil suspension through an H-cationite column by Stout at the University of California, and then this was used in the work of Harvard and Coleman (10). However, in solving the problem of exchangeable Al and H, the reverse process is of importance, i. e., the transfer of exchangeable ions from the soil to cationite. Two cationites were chosen for the experiments:[1] SBS and KU-2, the characteristics of which are given in the work of Pashkov and Titov (3). The exchange capacity of SBS cationite is less than that of KU-2, and for this reason we expected less transfer of Al from the soil to this cationite, and this was also borne out in the experiments. The Ca cationites were prepared in the following way: The cationites were washed with a 1% solution of HCl to purify them from other cations. Then they were saturated with calcium by treatment with a 10% solution of $CaCl_2$, and then with a solution of $Ca(CH_3COO)_2$ until the solution flowing from the cationite showed a neutral reaction, and then again with a solution of $CaCl_2$. Then the cationites were washed with water until there was no more Cl reaction. The absence of exchange acidity in the Ca cationites was checked by treating them

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[1] Analyst A.O. Zagaynova and K.D. Dovzhenko participated in the experiments.

ith a solution of 1 N KCl. The Ba cationites
ere prepared in the same way.

The experiments were conducted in the fol-
wing way: The weighed portion of the soil
as passed through a sieve with 0.25 mm open-
g and mixed with a weighed portion of cation-
e powder not passing a 0.5 mm opening sieve.
he mixture of cationites and soil was immersed
ith 100 ml of H_2O. The suspension was agitated
r one hour, then set aside for 20 hours, when
was again agitated for one hour. The cation-
e was separated from the soil on a 0.5 mm
eve by washing it with water. The content of
xchangeable hydrogen and aluminum in the
tionite freed of soil was determined by treat-
g it with a 1 N solution of KCl and titration
the filtrate with and without the addition of
aF (5). The content of active aluminum and
e exchange acidity were also determined for
e soil washed from the cationite.

Two soils were selected for the experiments.
these soils the exchangeable acidity was al-
ost equivalent to the content of aluminum in
e salt extract. One was a red earth from
naseuli, which contained 2.12 meq Al^{3+} and
06 meq H^+, and a sod-podzolic soil containing
2 meq Al^{3+} and 0.02 meq H^+. Let us give
e results of a few experiments. After the
periment, 2 g of the cationite washed free
soil were agitated for 1 hour with 100 ml of
1 N solution of KCl. It took 5.5 ml of 0.02 N
aOH to titrate the acidity of the solution when
aF was not added, but only 0.5 ml when NaF
as added. Consequently, the cationite ac-
ired, as a result of interaction with the soil,
exchange acidity caused by aluminum, since
dition of NaF to the solution results in titra-
on of the H-ion, and without the addition of
aF the titration involves the H^+ and Al^{+++} (5).

In the second experiment we used 5 g of KU-
Ca cationite and 40 g of red earth. After the
d of the experiment, 0.37 meq of Al^{+++} and
ly 0.01 meq of H^+ were displaced from the
tionite (by treating it with 125 ml of a 1 N
lution of KCl) after it had been washed of
il. The soil washed from the cationite con-
ined 1.0 meq of Al^{+++} and 0.02 meq of H^+
r 100 g, according to data for the 1 N KCl
tract. The original soil contained 2.12 meq
active Al, while the soil washed from the
tionite and the cationite contained 1.92 meq
Al^{+++} (computed for 100 g of soil). This
dicates good agreement of data with such
nall readings in the titration of solutions.

In the third experiment we used the same
il but with KU-2 Ba-cationite. In this experi-
ent we used 5 g of cationite and 100 g of
il. At the end of the experiment, after the
tionite had interacted with the soil, we found
it 0.31 meq of exchangeable aluminum and
)2 mg of exchangeable hydrogen.

In the fourth experiment we studied the
teraction of 5 g of KU-2 Ca cationite with
g of sod-podzolic soil. After the interaction
the soil and the cationite we found 0.14 meq
Al^{+++} and 0.01 meq of H^+ on the cationite.
the soil washed from the cationite we found
73 meq of exchangeable aluminum and 0.02
eq of hydrogen (computed for 100 g of soil).
e original soil contained 1.20 meq of Al^{+++},
and after the experiment the soil and the cationite contained 1.08 meq, computed for 100 g of soil.

In the fifty experiment we studied the interaction of cationite and peat soil containing both exchangeable aluminum and exchangeable hydrogen. In the salt extract of the peat soil (top-layer peat, Red'kino, Moscow Region) we found 3.95 meq of exchangeable aluminum and 2.32 meq of exchangeable hydrogen for 10 g of soil and 200 ml of solution. After the interaction of 10 g of soil and 5 g of SBS Ba cationite, 0.94 meq of Al and 0.70 meq of H-ion were transferred to the cationite.

Conclusions

1. In the interaction of sod-podzolic soils and red earth with different Ca- and Ba-cationites, there occurs a transfer of Al from the soil to the cationite and a decrease in the content of active aluminum.

2. The exchange of Al between the soil and the cationite occurs under conditions that exclude the possibility of acid solution of the soil aluminum compounds formed at the time of the exchange (the reaction of which explained the presence of Al in the salt extract of the soils). Data from the analysis of the salt extract of podzolic, red earth, and peat soils show the presence in them of aluminum and hydrogen compounds capable of exchange which determine the exchangeable acidity of the soil.

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REGULATION OF NITRIFICATION PROCESSES ON CISCAUCASIAN CARBONATE CHERNOZEMS DURING IRRIGATION

P. YE. PROSTAKOV, Stalingrad Agricultural Institute

Soil nitrogen is intimately involved in organic life. It appears together with plant and animal residues or in the bodies of soil microbes. A slight amount of nitrogen, chiefly in the form of ammonia, enters the soil with rain.

Nitrogen is found in organic matter in proteins and, to a lesser extent, in amino acids, amides, and other compounds. The organic form of nitrogen is not readily available to plants. Organic nitrogen compounds are mineralized by microorganisms; nitrogen is released in the form of ammonia, which is then oxidized to nitrites and to nitrates. Thus, in addition to organic nitrogen the soil contains ammonium salts, nitrites, and nitrates, which are the forms serving as the chief sources of nitrogen for plants. They are the products of hydrolysis and decomposition. The rate of mineralization of organic nitrogen, according to the research of Antipov-Karatayev and Filippova (1), can be judged from the number of intermediate forms. In this respect the Ciscaucasian carbonate chernozems (Urozhaynenskiy rayon, Kabardino-Balkarian ASSR) exhibit of peculiarities. These chernozems contain substantial amounts of total nitrogen (2525-2685 mg/kg of dry soil), but the content of easily hydrolyzed nitrogenous compounds is meager (61 to 21 mg — 2.15% of the total nitrogen). The total amount of mineral forms of nitrogen is close to that of easily hydrolyzed nitrogen (89%-98% of the latter).

Nitrates are predominant among the mineral forms of nitrogen in Ciscaucasian carbonate chernozems — 63%-75%. Consequently, the process of nitrification in these soils is fairly rapid, as shown by our data.

The conversion of organic nitrogen into a form available by plants, including nitrates, takes place spontaneously and not always with the completeness and speed required by the plants. Our investigations have shown (12) that various methods of cultivation may result in accumulation by the soil, especially chernozems, of such amounts of mineral nitrogen at the expense of the organic forms as to ensure the highest yields.

We regard methods to regulate the nitrification processes through cultivation, irrigation, and fertilization as a powerful tool in our socialist agriculture to raise soil fertility and crop yield.

The nitrification processes can be intensified by optimum temperature, adequate moisture, and presence in the soil of the necessary amount of nitrogen-containing organic matter. By changing these conditions we can significantly affect the nitrification rate.

The present methods of irrigation change the physical properties of the soil while regulating water relations and frequently create unfavorable conditions for nitrification. That is why improvement of the physical properties of the soil after irrigation is an indispensable condition for increasing the effectiveness of irrigation. Harrowing, cultivation, and plowing, provided there is adequate moisture, improve the physical condition of the soil and always increase the nitrates. However, excessive pulverization and desiccation by frequent cultivation decrease the nitrates. We observed that after excessive cultivation and disiccation of the soil under corn the amount of nitrates was negligible — 5-10 mg/kg of soil — and the yield was small — 25.6 cntr/ha of grain. With good cultivation that did not result in desiccation the amount of nitrates was 25-40 mg; the corn yield increased to 35.5-42.3 cntr/ha and to 95-110 cntr/ha after irrigation.

Nitrates may be accumulated by regulating the temperature of the soil. Many years of experience with irrigation have shown that warm water markedly increases the yield of many crops. Thus, rice fields are frequently irrigated with water first warmed on unplanted areas. Subsequent irrigations heat up the soil and thereby intensify the microbiological processes. We confirmed this by experiments (13) on wetting soil with water heated by K. G. Trofimov's solar heating installation consisting of flat iron boilers with ribbed surface placed close to the experimental plot. The resultant analytical data show (Fig. 1) that nitrification substantially intensified both in a fallow field and in a field under cotton. Maximum intensification occurred when the water was heated to 45-50°C. The process was somewhat less intense when the water was 30°C. According to Lepnev (8), more nitrates were formed after night irrigation than after day irrigation. The cotton yield increased by 3 cntr/ha (16) and the peanut yield by 2.0-2.5 cntr/ha corresponding to the change in nitrate content of the soil in the heated variants.

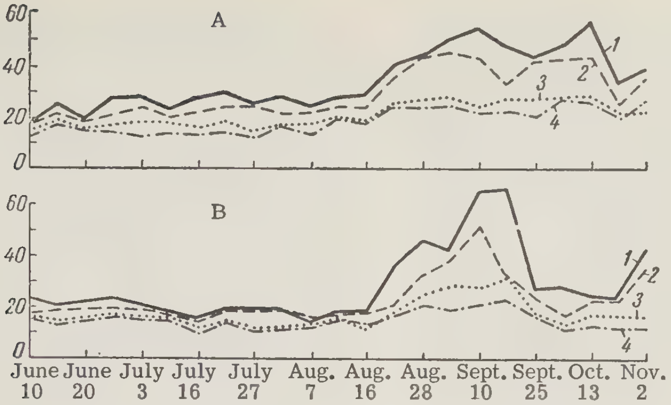

Fig. 1. - Dynamics of nitrates following warm-water irrigation (in mg/kg of absolutely dry soil).

A - bare fallow M = 2000 m^3/ha, 0 to 20 cm; B - cotton M = 2000 m^3/ha, 0 to 20 cm. 1 - irrigated with warm water 45° to 50°C; 2 - irrigated with warm water 30°C; 3 - ordinary night irrigation; 4 - ordinary day irrigation.

We later showed (11, 14) that nitrification ould be stimulated by fall and even winter rigation. This experiment was based on an riginal idea by Krylov (6), which is essential- as follows. Drought is more or less a hermal phenomenon. The damage resulting rom it (atmospheric, soil, and physiological ryness) is due to excessive heat and destruc- on of the thermal balance in the plants. It s evident from the investigations of Krylov on ie Altatinskiy and Dobryninskiy irrigated areas f Saratov oblast' that the thawing of soil frozen a depth of one meter is delayed 15-20 days. he temperature of the soil under spring wheat as 3-5°C lower than after a single summer rigation during the growing season. This ooling reduced the temperature peaks and cre- ted a temperature regime conducive to intensi- ed nitrification. The nitrate content increased oth on the plots given a single winter irriga- on and on those where it was combined with ummer irrigation. There was no decrease nitrates after summer irrigation, as is requently the case after a normal summer rigation. Thus, the yield of spring wheat ose to 18.9-22 cntr/ha (as compared with a ield of 16.2 cntr/ha without irrigation). These vo examples show that nitrification can be in- uenced by various methods of controlling the mperature of the soil.

The nitrification processes were markedly ccelerated when perennial grasses were in- uded in the crop rotation. Bolotnikova's udies and our own indicated that after two or ree years of inclusion of alfalfa in the rota- on, the amount of nitrate nitrogen in the plow yer (0-30 cm) was 200-300 kg/ha, while the trification processes under the following rops were intensified for the next two or ree years. The physical properties of the oil improved at the same time. For example, ggregate analysis (according to Pavlov [10]) iowed that by the end of the second year of e grasses the quantity of macroaggregates plots under alfalfa was much greater than on continuously cultivated soil, especially on irrigated alfalfa fields. Most of the macroaggregates were found under alfalfa alone after irrigation (37%-55%), lesser amounts under alfalfa sown under irrigated winter wheat, still less with alfalfa alone without irrigation, followed by alfalfa sown under winter wheat without irrigation; the smallest amount of aggregates was observed on the continuously cultivated soil. The nitrification capacity of the soil changed correspondingly; it was greatest with irrigated alfalfa alone — 102.12 mg of nitrogen per kilogram of dry weight after 30-day composting — and smallest on the continuously cultivated soil — 54.05 mg per kg of soil. The sharp rise in nitrification capacity after the grasses was due to the substantial accumulation of root residues in the soil and their large nitrogen content, so that the nitrogen in organic matter increased from 0.280%-0.338%.

The length of time that alfalfa remains in the crop rotation has a marked effect on the structure and nitrification capacity of the soil, particularly if irrigated. We observed changes in the soil aggregation in relation to the presence of alfalfa. Soils under grain crops proved to be more dispersed than those under alfalfa. Irrigation left their soil aggregates virtually unchanged. Owing to the alfalfa the amount of large aggregates was 1-1/2 times greater than on continuously cultivated soil. The maximum aggregates formed in soil occurred the second and third years after the alfalfa was planted and was most pronounced in the case of irrigated alfalfa; it was much less marked when the alfalfa was not irrigated.

The nitrification capacity of the soil was greatest three years after alfalfa was included in the crop rotation. The maximum accumulation of nitrates of monthly composting of different ages was observed after three years under alfalfa (17-20 mg of nitrate nitrogen per kilogram of dry soil more than under two-year-old alfalfa). It is interesting to note that there was a difference in nitrification under irrigated and nonirrigated alfalfa. We observed at the start of the experiment and ten days after composting that nitrification was much more intense under nonirrigated alfalfa. The production of smaller amounts of nitrates under irrigated alfalfa during the first two days of observations was due primarily to weakening of microbiological activity rather than to deterioration of its physical properties. Nitrification in irrigated soil increased with the renewal of microbiological activity. There were much nitrates by far under irrigated than under nonirrigated alfalfa by the end of the observations (30 days of composting). The total content of nitrogen in the roots of irrigated alfalfa was higher (0.320% as against 0.283%). The nitrogen content decreases with time (from 0.320%-0.274%).

Perennial bunch grass plays a very important part in the structure-forming processes of the soil, but has not been adequately investigated. The resultant biochemical processes, in particular, have been given very little attention. A detailed study of the root system of the grass has shown that it is exceptionally dense both in the arable and subarable layers, thus explaining why it is bound to affect the soil.

Our study of the aggregation has revealed that the arable and subarable layers of the soil are substantially changed by perennial bunch grass. All the perennial grasses examined were able to form a great many water-stable aggregates. The following enumeration is in order of increasing action: bluegrass, wheatgrass, quackgrass, perennial ryegrass, and timothy. This pattern of aggregate formation depends both on the size of the root system and on its structure. For example, timothy with its fine, well-developed root system yielding up to 176.8 cntr/ha had the strongest effect on the formation of macroaggregates. Among the perennial leguminous herbs sainfoin and yellow alfalfa had the most beneficial effect on soil structure in the absence of irrigation. Alfalfa was somewhat less effective in the formation of aggregates than sainfoin and yellow alfalfa.

The data on nitrification capacity show that the initial nitrate content under perennial grasses was much smaller than on continuously cultivated soil. During the course of a month's observations, nitrification capacity of soil under grasses was also lower for the most part. On the other hand, the perennial legumes doubled the accumulation of nitrates.

The planting of perennial grasses alone, therefore, substantially improves the soil aggregation (which is better than under perennial legumes), but at the same time it markedly reduces nitrification capacity. We attribute this to nitrogen deficiency of the soil, because the root residues of the grasses contain less nitrogen than the legumes. For example, the roots of timothy contain 1.28% nitrogen, quackgrass 1.28%, wheatgrass 1.18%, and bluegrass and perennial ryegrass 1.09-1.1%, whereas alfalfa roots of the same age contain 2.10%. This suggests the desirability of using the good physical properties of the soil created by the perennial bunch grasses. Increasing their nitrification capacity by planting grasses with legume (in a variety of mixtures) contributes to fertility. Our investigations have shown that the soil aggregation under perennial grass-leguminous mixtures deteriorated only slightly in comparison with the planting of perennial grasses alone, but it exhibited greater improvement than when legumes alone were planted. For example, with wheatgrass alone the subarable layer contained 47.11% macroaggregates (>0.25 mm), with a mixture of alfalfa and wheatgrass 39.07%, with quackgrass alone 48.21%, and with a mixture of quackgrass and alfalfa 51.74%. The total nitrogen content increased substantially under the mixtures of grasses as a result of legumes. Under the legume-grass it was not much less than under alfalfa alone. The arable layer (0-20 cm) of the soil under alfalfa contained 0.294% nitrogen, while the subarable layer (20-40 cm) contained 0.245%; under alfalfa plus quackgrass the figures were 0.287% and 0.224%, respectively.

The nitrification capacity also increased after sowing grass mixtures as compared with perennial grasses alone. The greatest capacity was exhibited by a mixture of alfalfa plus wheatgrass — 102.75 mg of nitrates per kilogram of soil after a month of composting. Nitrification capacity was generally quite high under grass-legumes mixtures and was almost as much as under legumes. The gradual decomposition of the root system of the grass-legumes mixtures, which have a higher content of nutrients, is very important in maintaining soil fertility for some time after the grasses are plowed under.

Consequently, different types of grasses may significantly affect the physicochemical and biological properties of the soil and increase its nitrification capacity. Our data indicate that the nitrification can be substantially intensified by the addition of organic fertilizers. Nitrates accumulated much more slowly in nonfertilized soil than in soil that received organic fertilizers. Compost with organic matter revealed a marked increase in nitrates by the third date of observations, i. e., after a month of experimentation. The nonfertilized soil contained 23.82%, soil + bone meal 90.65%, soil + sunflowerseed cake 81.48%, soil + ground soybean 72.06%, and soil + manure 46.91% nitrates per kilogram of dry soil.

The timely cultivation of Ciscaucasian chernozems with extensive organic nitrogen contents intensifies nitrification and is an important means of supplying plants with nitrogen. Summer rains cannot cause significant losses of nitrogen, because leaching is largely checked owing to slight water penetration into the soil. Leaching is possible only after irrigation or in the fall during the period of heavy rains. Biological absorption here may well prevent the nitrates from being leached. The conversion of mineral nitrogen into organic nitrogen will impair the yield significantly only if the nitrates are lost during the growing period. If the microbes absorb the nitrate nitrogen on fallow and other areas in the fall, leaching is prevented. After the bacteria die, the absorbed nitrogen reappears in mineral form to serve as a nutrient for cultivated plants. This can be done by plowing in coarse, nondecomposed straw manure, or even straw, which is immediately attacked by microorganisms, chiefly those which break down cellulose. It will be noted that crops can become impoverished on soils insufficiently supplied with organic nitrogen turning into nitrates. We recommend the use of straw (high stubble) or fix nitrogen on the Ciscaucasian chernozems which accumulate considerable amounts of nitrate nitrogen (from 150-300 kg/ha) in the fall. This applies not only to the use of straw late in the summer and fall but, also, under certain circumstances, to the plowing of fallow in the spring.

Our observations of the nitrification on irrigated bare fallow with coarse manure and straw plowed in, show that the amount of nitrates decreased (Fig. 2) as compared with nonfertilized fallow. The decrease was undoubtedly due to biological fixation of the nitrogen. The following spring there were more nitrates under winter wheat sown on fallow fertilized with manure and straw than on nonfertilized fallow. The yield of winter wheat on the nonfertilized fallow was 27.9 cntr/ha and on the fertilized fallow 30.7 cntr/ha, i. e., an increase of 2.8 cntr/ha or 10.03%.

Nitrification can also be controlled by adding mineral compounds when they are present in small quantities in the soil or the organic matter is weakly mineralized (wide ratio of carbon to nitrogen). According to L'gov (9), the addition of nitrogen fertilizers alone to Ciscaucasian chernozems intensified the process, but did not produce as much nitrates as a single application of phosphorus did. With composting of the soil to which ammonium sulfate had been added at the rate of 100 kg/ha of nitrogen, in 30 days, the 0-20 cm layer showed 107.07 mg of nitrate nitrogen, the 20-40 cm layer 64.65 mg. However, with composting of the soil to which 100 kg of phosphorus in the form of superphosphate had been added along with the foregoing amount of nitrogen, the nitrate nitrogen came to 112.22 and 87.45 mg/kg of dry soil, respectively. Consequently, phosphorus fertilizers intensify the nitrification process.

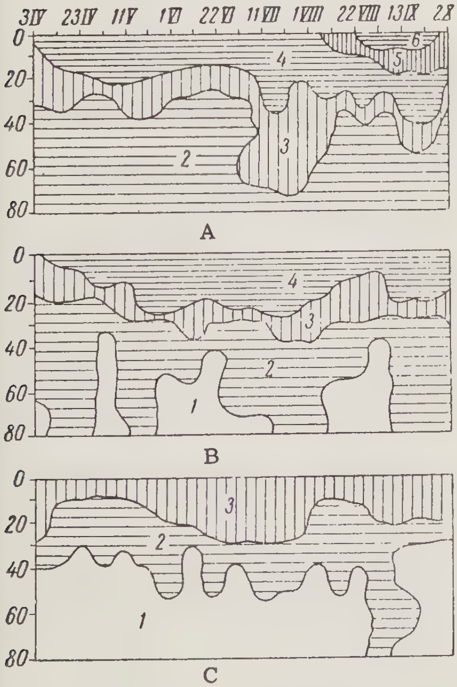

Fig. 2. - Chronogram of nitrates on a fallow field fertilized with coarse manure.

A - nonirrigated, nonfertilized plot; B - nonirrigated, fertilized with manure; C - irrigated, M = 1600 m^3/ha, fertilized with manure. 1 - about 2 mg; 2 - 2 to 5; 3 - 5 to 10; 4 - 10 to 20; 5 - 20 to 30; 6 - 30 to 40 mg.

The Ciscaucasian carbonate chernozems are characterized by the high potential energy of the nitrification; the organic and ammonia nitrogen of the fertilizers here is oxidized into the nitrate forms. Our research showed that nitrification ends within two or three weeks after various crops are given a supplementary feeding of ammonium nitrate or ammonium sulfate. Consequently, the addition of nitrogen fertilizers to these soils results chiefly in the accumulation of nitrate nitrogen, which ultimately is the main source of nitrogen for the crops in the zone under investigation. However, the nitrate compounds of nitrogen are easily leached from the soil because of rain or irrigation owing to their ready solubility (as pointed out previously), but with summer evaporation of the moisture they rise to the top layers of the soil by capillary action. This removes a good deal of available nitrogen from the root zones, thereby limiting the use of nitrogen fertilizers by the plants. Hence, it is necessary to slow the nitrification to facilitate the accumulation of nitrogen in the form of ammonia. Ammonia in the Ciscaucasian carbonate soils with their high calcium carbonate content, as is evident from the work of D. N. Pryanishnikov (16), is superior in every way to nitrate for plants.

In order to determine whether the nitrification could be slowed up and the accumulation of ammonia nitrogen increased, we studied the ammonia and nitrate regime in carbonate chernozems fertilized with various forms of nitrogen fertilizers of organic and mineral origin. Zhorik (2) used different organic mixtures and was quite successful in reducing the availability of nitrogen compounds. Biological fixation of nitrogen in the form of only slightly soluble organic compounds helped to check the pronounced migration of nitrate nitrogen. The nitrogen was released after decomposition of the resultant organomineral compounds and again became available to the plants, remaining longer in the root zone. This finding was confirmed by Kolesnikova (4), who worked under our guidance on Ciscaucasian carbonate chernozems near Groznyy. Under optimum moisture and temperature conditions nitrification proceeded fairly rapidly following the addition of fertilizers to the experimental plots, because the soil contains an abundance of calcium carbonate, which neutralizes the acid products of this process. The addition of organic and organomineral fertilizers the first two weeks after composting caused a decrease in the amount of nitrates as compared with the soil fertilized with mineral compounds. The reason is that the decomposition of the organic matter added is accompanied by slight biological absorption of the mineral compounds and their conversion into organic compounds of the protein plasma of the microorganisms. Within two weeks, and particularly a month after composting, an accumulation of nitrates was noted in all the experimental treatments. The treatment involving the organomineral fertilizers was unusual for the meager nitrate nitrogen content of the soil; a month after composting, the mineralization of the organic matter began to predominate over the synthesis. The synthetic slow-acting nitrogen fertilizers (urea-forms), products of the synthesis of urea and formaldehyde, also work on the same principle (5). The urea-forms with the proportion of urea to formaldehyde in the range of 1.4-2.0 apparently resemble ammonium sulfate and bone meal in degree of nitrification, but there is very little nitrification when the proportion is 0.88 to 103. We learned by experimentation that the degree of nitrification was always adequate when the proportion was 1.18 to 1.36. They can therefore be regarded as slow-acting nitrogen fertilizers. Lazarev's research (7) indicates that partial sterilization of the soil is another method of slackening nitrification, e.g., through the application of calcium cyanamide.

According to Zhorikov (3), calcium cyanamide is quite different from other nitrogen fertilizers in the nature of its effect on the nitrogen regime of the soil. It markedly inhibits nitrification and checks the accumulation of substantial amounts of ammonia. It forms dicyanamide, which has a toxic effect on microorganisms. After some time in the soil, dicyanamide is converted into urea and inhibition of nitrification comes to an end. The use of calcium cyanamide (25% nitrogen) with ammonium nitrate (75% nitrogen) promoted the accumulation of ammonia nitrogen during the growing period.

Sharp differences also showed up in the distribution of nitrate nitrogen through the different soil horizons. Substantial amounts of nitrates were found in the top layers of plots fertilized with ammonium nitrate. Much less nitrate nitrogen was lost in the top layer when ammonium nitrate was applied with calcium cyanamide. The greatest accumulation was noted in the 5-25 and 25-40 cm layers, where the main root mass of crops is to be found. Thus, the combined application of these fertilizers in the indicated proportions created highly favorable conditions for plant nutrition. Our research on Ciscaucasian carbonate chernozems completely confirmed the rule that the nitrification process is inhibited by the addition of ammonium nitrate combined with calcium cyanamide.

With respect to a more uniform distribution of nitrates in time, the periods when the fertilizers — principal and supplementary — are added are of great significance. The addition of fertilizers causes an uneven distribution of nutrients in the soil and, as a result, different feeding conditions for each root.

The spacing of nutrients in the soil is also important as far as the effectiveness of fertilizers is concerned, especially on irrigated lands where the irrigations intensify the processes of absorption of nutrients and movement of fertilizers. Our experiments with sugar beet showed that the best distribution of nitrate nitrogen occurs when nitrogen fertilizers are added three to five times and the irrigation rate is 3000-4500 m^3/ha.

One-sided cultivation during the summer results in considerable accumulation of nitrate nitrogen on the ridges of the rows. After cross-cultivation, however, when a good deal of the soil is shifted from the ridges to the spaces between the rows, the nitrates are uniformly redistributed, and the subsequent irrigations tend to leach them down into the root zone where they are more readily absorbed by the plants. With cross-cultivation every irrigation is to be regarded as a special supplementary feeding with nitrogen, which remains not utilized in the ridges of the rows after ordinary row cultivation.

The foregoing examples are just a few of the possible ways by which the nitrification in the soil can be controlled. It is clear that with due regard for the characteristics of nitrification under the different crops we can intensify or weaken the processes and thereby increase the yields.

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RESIDUAL EFFECT OF SUPERPHOSPHATE IN THE SMOLNITZA GROUP OF SOILS

M. RADENKOVA-KARAIVANOVA and IVAN DONCHEV, Soil Institute, Bulgarian Academy of Sciences

The smolnitza group of soils is widespread in the plains regions of southern and southwestern Bulgaria (10). These soils cover an area of about 600,000 hectares or almost one-eighth of the cultivated land of the country. Smolnitzas are also found elsewhere on the Balkan peninsula-Yugoslavia, the European part of Turkey, and Greece. The leached subgroup of smolnitza is particularly common.

According to the literature, smolnitzas in general are naturally productive soils. Their productivity is largely due to the marked thickness of the humus and root layers, considerable moisture capacity, adequate amounts of nitrogen and potassium, and weakly acid to neutral reaction. Smolnitzas also possess a number of somewhat negative features as far as crops are concerned, e. g., unfavorable water and physical properties caused by their fine texture, meager amounts of available phosphates, etc.

The problem of increasing the fertility of smolnitzas is closely contingent on improving the phosphate regime. This has been fully confirmed by the results of extensive experiments in Bulgaria with fertilizers (2, 8). They show that smolnitzas respond vigorously to phosphorous fertilizer, particularly if combined with a nitrogen fertilizer.

The residual effect of phosphorous fertilizer on smolnitzas has not been investigated in Bulgaria. The present paper is an account of field work undertaken to study the residual effect of superphosphate on leached smolnitzas.

The experiments were performed on the experimental field of the Soil Institute of the Bulgarian Academy of Sciences 12 km north of Sofia. The soil has the following characteristics: A hor. — 0-10 cm; clay loam (particle diameters <0.001 mm — 46.4% and <0.01 mm — 76.4%); adsorption capacity (according to Gedroyts) — 47.0 meq per 100 g of soil; adsorbing complex saturated more than 90% by calcium and magnesium; clay minerals represented by the montmorillonite group; maximum hygroscopic moisture — 15.6%, wilting moisture — 23.4%; pH in H_2O — 6.5, in KCl — 5.4; humus — 4.50%; total nitrogen — 0.22% hydrolyzable nitrogen (according to Tyurin and Kononova) — 70 mg per kg of soil; available phosphorus (according to Kirsanov) — <1.25 mg of P_2O_5 per 100 g of soil and exchangeable potassium (according to Nering) — 25 mg of K_2O per 100 g of soil.

The portion of the field where the experiments with the fertilizers were performed was plowed up in 1947. For 10-15 years prior to that time it was not cultivated, being used as a pasture.

The field experiments were set up in 1949 in two rotations: a) four-field rotation with the sequence of vetch-oats mixture, winter wheat, corn, and oats; b) eight-field grass rotation; grass mixture (tall ryegrass and alfalfa — two fields), wheat, corn, oats, vetch-oats mixture, wheat, and sunflower.

From 1949 to 1953 inclusive, fertilizers were applied to each crop (except the grass mixture the second year) according to the following plan: 1) without fertilizer — 0; 2) powdered superphosphate — 40 kg/ha of P_2O_5 — P_1; 3) 80 kg/ha of P_2O_5 — P_2; 4) 120 kg/ha of P_2O_5 — P_3; 5) 80 kg/ha of P_2O_5 and supplemental 40 kg/ha of P_2O_5 — P_4; 6) as on plot 2, + 40 kg/ha of nitrogen (ammonium nitrate) — P_1N_2; 7) as on plot 3, and 40 kg/ha of N — P_2N_2; 8) as on plot 4, + 40 kg/ha of N — P_3N_2; 9) as on plot 5, + 40 kg/ha of N — N_4N_2. P. Radomirov, director of the experimental field from 1947 to 1951, worked out the plan of the experiments. The usual agricultural practices of this region were followed for the individual crops: deep plowing and early cultivation for the spring crops, preplanting plowing to a depth of 18 cm for the winter crop.

The total annual rain in the region of the experimental field averaged 606 liters/m² during the preceding 25 years. During the years of the experiments (1949 to 1956) there were substantial variations, ranging from 330 liters/m² in 1951-1952 to 649 liters/m² in 1950-1951.

Since fertilizers were applied to all the fields in the crop rotation every year from 1949 to 1953 inclusive, account was taken of the cumulative effect of the fertilizers added in one year and the residual effect of the fertilizers of the preceding years.

The results of adding fertilizers from 1949

Table 1

verage yields in centners per hectare after direct fertilization of crops in a four-field rotation from 1949 to 1953.

'ertilizer	Vetch-oats hay		Winter-wheat		Corn		Oats	
	For 3 yrs. (1950,1951, and 1953)	Increase as a%	For 3 yrs. (1950,1951 and 1952)	Increase as a%	For 4 yrs. (1950,1951 1952,1953)	Increase as a%	For 3 yrs. (1949,1950 and 1953)	Increase as a%
O	49,2	100	19,1	100	34,2	100	14,9	100
P_1	55,3	112	28,8	150	36,9	107	20,3	136
P_2	55,8	113	28,7	149	37,6	110	20,9	140
P_3	57,4	117	28,2	147	38,7	113	20,4	137
P_4	58,9	120	30,0	156	39,6	115	22,3	150
P_1N_2	65,8	134	30,8	160	40,4	118	22,3	150
P_2N_2	69,7	142	32,2	168	42,7	124	24,0	161
P_3N_2	67,9	138	31,2	162	41,3	121	22,9	153
P_4N_2	63,8	128	32,2	168	41,4	120	25,0	167

ote: Comma represents decimal point.

Table 2

verage yields in centners per hectare after direct fertilization of crops in an eight-field grass crop rotation from 1949 to 1953

ertilizer	Winter wheat				Corn		Oats		Vetch-oats mixture	
	Previous crop									
	Grass mixture (1951-1953) grain	Incr. as a %	Vetch-oats mixture (1950-1953) grain	Incr. as a %	For 3 years (1951-1953) grain	Incr. as a%	For 4 years (1949-1953), grain	Incr. as a%	Dry hay for 1950-1953	as a %
O	12,8	100	17,8	100	42,6	100	16,8	100	45,9	100
P_1	18,8	147	28,1	158	47,6	112	23,9	142	54,0	116
P_2	20,0	156	28,2	158	51,1	120	25,6	152	52,2	114
P_3	20,4	160	27,6	155	49,9	117	24,2	144	53,5	116
P_4	20,4	160	38,3	159	49,9	117	27,1	162	54,7	119
P_1N_2	20,9	164	31,5	177	51,3	120	25,6	152	63,1	137
P_2N_2	21,5	169	32,4	182	51,0	120	28,3	166	67,6	147
P_3N_2	21,2	166	31,8	176	55,0	129	28,1	168	64,4	140
P_4N_2	21,0	165	33,4	188	53,2	125	30,2	180	66,2	144

ote: Comma represents decimal point.

953 are shown in Tables 1 and 2. It is
lent that phosphorous fertilizers applied
arately or in conjunction with a nitrogen fer-
:er proved to be highly effective.

'ertilizers were not applied from 1954 on,
the residual effect was investigated. The
dual effect of phosphorous fertilizers was
erved for the next five years (1954 through
3). Table 3 shows the summarized results
ie residual effect for 1954, 1955, and 1956.
data reveal that superphosphate has a
iounced residual effect on smolnitzas, par-
larly with winter wheat and vetch-oats
ture. The effect on increasing the yield
ats, sunflower, and corn is considerably
.

The experimental findings indicate that phosphorous compounds, easily assimilated by plants, are produced by the interaction of superphosphate and smolnitza. Soil samples were taken from the fields of the eight-field rotation in the summer of 1956 to clarify this question. The samples were taken from the plow layer at a depth of 20 cm on the following plots:

No. 1 — control, no fertilizer the year the field was started (1948); No. 4 — from 1949 to 1953 inclusive, 120 kg/ha of P_2O_5 in the form of powdered superphosphate was applied annually, or a total of 600 kg/ha of P_2O_5 for the five years; from 1954 on, the residual effect of the fertilizers on the crops was investigated — in 1954, on winter wheat; in 1955-1956, on

Table 3

Average yields in centners per hectare in a four-field crop rotation and in an eight-field grass crop rotation with a study (1954-1956) of the residual effect of phosphorus fertilizers

Fertilizer 1949-1953 inclusive	Four-field crop rotation								Eight-field grass crop rotation													
	Vetch-oats mixture		Winter wheat		Corn		Oats		Grass mixture		Winter wheat after grass mixture		Vetch-oats mixture		Winter wheat after vetch-oats mixture		Corn		Oats		Sunflower	
	Hay for 2 years (1954, 1955)	Incr. as a %	Hay for 3 years (1954, 1955, 1956)	Incr. as a %	Grain for 1956	Incr. as a %	Grain for 2 years (1954, 1956)	Incr. as a %	Hay for 3 years (1954, 1955, 1956)	Incr. as a %	Grain for 3 years (1954, 1955, 1956)	Incr. as a %	Hay for 3 years (1954, 1955, 1956)	Incr. as a %	Grain for 2 years (1955, 1956)	Incr. as a %	Grain for 3 years (1954, 1955, 1956)	Incr. as a %	Grain 1954	Incr. as a %	Grain for 2 years (1955, 1956)	Incr. as a %
O	35,3	100	15,0	100	19,4	100	10,4	100	12,3	100	14,9	100	29,3	100	15,0	100	24,3	100	16,5	100	16,0	100
P_1	44,0	125	18,0	120	23,4	121	11,9	114	14,0	114	16,0	107	37,7	129	18,5	130	27,9	115	19,3	117	18,5	116
P_2	46,1	130	23,3	155	24,1	124	12,3	118	16,5	134	16,9	113	37,7	129	22,2	148	30,0	123	20,4	124	19,1	114
P_3	45,7	129	22,4	150	23,6	122	11,9	114	16,9	137	17,1	111	41,9	143	21,3	142	30,0	123	20,1	122	19,0	119
P_4	45,6	129	23,0	153	23,0	119	12,3	118	15,4	125	18,2	122	40,7	140	22,8	152	29.5	121	20,0	121	18,1	113
P_1N_2	44,7	127	20,2	135	24,3	125	13,9	135	17,1	139	18,1	122	39,5	135	20,9	134	29,3	120	21,1	128	19,2	120
P_2N_2	46,3	133	23,0	153	26,0	134	12,7	122	18,4	150	17,1	120	42,3	144	21,8	145	30,3	124	22,4	136	18,9	118
P_3N_2	46,1	131	21,0	140	24,8	128	12,4	119	18,0	146	18,1	122	43,7	149	23,3	155	29,6	121	22,4	136	19,3	121
P_4N_2	45,6	129	23,4	156	25,4	131	13,2	127	15,0	122	—	—	44,8	153	23,5	157	30,1	123	23,4	142	19,3	121

Note: Comma represents decimal point.

e mixture of alfalfa and tall ryegrass; No. 12 from 1949 to 1952 inclusive, 40 kg/ha of O_5 (powdered superphosphate) and 80 kg/ha nitrogen (ammonium nitrate) were applied nually. In 1953, 120 kg/ha of P_2O_5, 120 :/ha of nitrogen, and 60 kg/ha of K_2O (potas- um sulfate) were applied. Consequently, a tal of 280 kg/ha of P_2O_5 was used for the five ears. Investigation of the residual effect of the rtilizer was started with 1954.

The group composition of the phosphates was termined in accordance with Chirikov's scheme. ne results are shown in Table 4.

The total amount of phosphorus was greater the plow layer of the fertilized plots than in at of the nonfertilized plot. The quantity of osphates of the first group of Chirikov in- eased on the fertilized plots. The data show at some of the phosphorous fertilizers added smolnitza remains soluble in carbonic acid en after five years of superphosphate-soil teraction. It is chiefly the low basic, alkaline- rth phosphates that are known to pass into a rbonic acid extract. In the soil of plot 4 ere was also an increase in the amount of osphates soluble in 0.5 n acetic acid. The ore basic alkaline-earth phosphates and part the aluminum phosphates likewise pass into is extract. The bulk of the water-soluble osphates added to the soil of plot 4 interacted th the soil to form phosphates soluble in 0.5 hydrochloric acid. These were chiefly alu- inum and iron phosphates, fluor-apatite, d phosphorite.

The soil of plot 12, unlike that of plot 4, ıs found to contain less phosphates soluble acetic acid than the control. Part of the superphosphate added to the soil of plot 12 passed into the group of phosphates soluble in hydrochloric acid and less readily soluble phosphates (the fifth group according to Chirikov).

The amount of available phosphates in samples from plots 1, 4, and 12 was determined by other methods: per Kirsanov (0.2 n hydrochloric acid); per Egner (lactate extract); in 1% citric acid; in 0.5 n neutral solution of ammonium fluoride per Brey and Kurt (Table 5).

It is evident from Table 5 that the soil of the non-fertilized plots contains only trifling amounts of available phosphates. The meager amount of readily available phosphates is characteristic of most Bulgarian smolnitzas (5, 6). The soil of plot 4 to which much more phosphorous fertilizer had been added than to the soil of plot 12 contains more readily available phosphates.

The data on group composition of the phosphates in the soils of the fertilized plots and on the content of readily available phosphates in the extracts normally used in chemical analyses indicate that the interaction of superphosphate with smolnitza soil results in the formation of comparatively less basic alkaline-earth phosphates and much more phosphates bound by aluminum and iron.

Let us compare the amounts of available phosphates in Kirsanov'a extracts, 1% citric acid, and 0.5 n solution of ammonium fluoride. The extract with citric acid and neutral solution of NH_4F was found to contain three to four times more phosphates than the much more acid

Table 4

Group composition of phosphates in a leached smolnitza according to Chirikov. Experiments with fertilizers in mg of P_2O_5 per 100 g of absolutely dry weight (analyst Ye. Taleva)

Plot No.	Fertilizer	Groups					
		I	II	III	IV	V insoluble	Total P_2O_5
		soluble					
		H_2O+CO_2	CH_3COOH	HCl	NH_4OH		
1	Nonfertilized	0,4	6,1	3,8	31,2	22,6	64
4	Annually from 1949-1953 inclusive, 120 kg/ha of P_2O_5	2,6	9,2	20,4	33,9	22,8	89
12	Annually from 1949-1952 inclusive, 40 kg/ha of P_2O_5 and 80 kg/ha of N. In 1953 the fertilizer was 120 kg/ha of P_2O_5 + 120 kg/ha of N + 60 kg of K_2O.	1,3	4,5	7,2	31,3	25,7	70

ote: Comma represents decimal point.

extract with 0.2 n hydrochloric acid by Kirsanov. It is highly significant that the soil of fertilized plots contains considerably more phosphates soluble in a fluoride extract. Consequently, a substantial part of the water-soluble phosphates added to the smolnitza were either converted into an exchangeable and readily sorbed form or into phosphates bound by aluminum (fluorine ions are known to be capable of combining with aluminum ions and forming complex salts).

In addition, phosphates sorbed on the surface of soil colloids may go into a fluorine-ammonium extract.

According to our data, the smolnitzas involved in the experiments with fertilizers are characterized by a weakly acid reaction, high exchange capacity, and considerable content of free iron and aluminum hydroxides soluble in an oxylate extract per Tamm and 5% KOH per Gedroyts. The nature of the phosphates formed from the superphosphate added to the soil is closely related to these properties.

We have already pointed out that the soils of the fertilized plots were found to contain somewhat more phosphates soluble in carbonic acid, acetic acid, and hydrochloric acid extracts by Kirsanov than the soil of the control. It is chiefly the weakly basic alkaline-earth phosphates that generally go into these extracts. In view of the weakly acid reaction of the soil, it seems improbable that $CaHPO_4$ or $Ca_3(PO_4)_2$ were formed in it. Chemical concentration of phosphate ions in the form of calcium phosphate is possibly only when the pH is above 6 (1, 14). It is much more likely that the newly formed alkaline-earth phosphates precipitated on the surface of clay minerals through exchangeable calcium. The literature indicates that this precipitation of alkaline-earth phosphates in base-saturated soils is possible within a pH range of 4-6. These phosphates are apparently available to the plants.

We must discuss here the conditions under which the phosphates retained by fertilized soil are assimilated by plants.

Published reports frequently stress the fact that phosphoric acid fixed in the soil by iron and aluminum is assimilated by plants with great difficulty if at all. It must be borne in mind, however, that the term "iron and aluminum phosphates" is a group concept used to designate compounds substantially different in structure, crystallinity, and combining form with soil constituents. Hence, the Fe and Al phosphates are not assimilated by plants to the same degree under different conditions. Unfortunately, we have no accurate method of measuring the presence in the soil of the individual forms of these iron and aluminum phosphates which differ in degree of availability to plants.

The view that phosphoric acid fixed in the soil by iron and aluminum is not assimilated or is assimilated with great difficulty by plants is supported by the fact that an unfavorable phosphate regime is normally characteristic of soils with a higher content of iron and aluminum phosphates produced as a result of the soil-forming process. Such are the podzolic, red earths, and lateritic soils which are marked by a weakly acid reaction, low content of organic matter, meager supply of nitrogen and other macro- and microelements, and depresse microbiological activity. It is to be expected, therefore, that soils lacking these negative characteristics present other conditions under which plants can mobilize and assimilate certain (less basic) iron and aluminum phosphates.

The humus content and intensity of its dynamics are highly significant for the nitrogen nutrition of plants and for the availability of soil phosphates, including related phosphorous nutrition. The mineralization of humus substances is known to increase the concentration of carbonic acid in the soil solution, resulting in the increased availability of alkaline-earth phosphates. In addition, humification creates humic acids, which may form stable complex compounds with iron and aluminum. During this interaction, phosphate ions combined with active forms of iron and aluminum may go into the soil solution.

There are numerous references in the literature to the increased availability of phosphates in soils with an acid reaction in the presence of organic matter (9, 14, 15, 16).

Organic acids may be produced in the soil during humification and from the secretions of plant roots (7). The latter are capable of increasing the solubility both of alkaline-earth phosphates and of phosphates bound by iron and aluminum.

It is evident from the foregoing that in considering the availability to plants of phosphates bound by iron and aluminum one must take into account the properties of the soil that facilitate or hinder the availability of these phosphorous compounds.

The smolnitzas involved in our experiments have properties that favor the mobilization and assimilation of phosphates bound by active forms of aluminum hydroxides or clay minerals sorbed on the surface. These include primarily an adequate supply of organic matter, nitrogen, and potassium and their weakly acid reaction. Smolnitzas are further characterized by their biological activity, for they contain many cellulose decomposing bacteria and actinomycetes and possesses marked nitrification capacity.

Hence, in evaluating the results of the action and residual effect of phosphorous fertilizers on smolnitzas one must bear in mind the properties that contribute to the high fertility of thes soils. On nonfertilized plots between 1949 and 1953 the yield of certain crops was above average: 19.2 cntr/ha of wheat; 49.2 cntr/ha of hay from a vetch-oats mixture; 42.6 cntr/ha of corn; and 16.8 cntr/ha of oats. This shows that the plants are able to obtain their phosphorous nutrition from phosphate of varying degree of availability. It is even possible that the plants also obtain phosphorus from phosphates insoluble in the acid extracts in the experiments. The data in Table 5 show that the soil of the nonfertilized plot contained a minimal amount of available phosphates. If under experimental conditions the plants were able

Table 5

Available phosphates passing into single extracts, in mg of P_2O_5 per 100 g of dry soil (analyst Ye. Taleva)

Plot No.	Fertilizer	Methods			
		Kirsanov	Egner	1% citric acid	0.5 n solution of NH_4F
1	Without fertilizer	1,25	0,6	3,3	1,6
4	Annually from 1949-1953 inclusive, 120 kg/ha of P_2O_5	4,3	4,8	11,3	11,8
12	Annually from 1949-1952 inclusive, 40 kg/ha of P_2O_5 and 80 kg/ha of N. In 1953, 120 kg/ha of P_2O_5 + 120 kg/ha of N + 60 kg/ha of K_2O were added	1,25	1,1	4,7	3,4

Note: Comma represents decimal point.

to obtain natural phosphates that were virtually insoluble in acid extracts, they could assimilate much more easily phosphates freshly sorbed on the surface of clay minerals or on the surface of aluminum or iron hydroxides.

This suggests that the reason for the prolonged residual effect of superphosphate revealed by our experiments with fertilizers is to be sought chiefly in the fact that owing to the general level of fertility of smolnitzas, newly formed phosphorous compounds are readily assimilated by plants. Moreover, our findings indicate that erroneous conclusions can sometimes be drawn regarding the degree of retrogradation and fixation of phosphorous fertilizers if they are based solely on the data of laboratory experiments involving a determination of the capacity of soils to absorb the water-soluble forms of phosphorus.

In assessing the extent of fixation and retrogradation of phosphorous fertilizers, it is much more important to know the forms in which phosphorus is fixed by the soil and the conditions under which the plants can mobilize and assimilate these phosphates. The absorption and retrogradation of phosphorous fertilizers should not be regarded purely as chemical and physicochemical phenomena. The main criterion for the fixation of phosphorus fertilizers by the soil are plants, i. e., their capacity to assimilate newly formed phosphorous compounds. That is why the fixation and retrogradation of phosphorous compounds must be studied in relation to plants and the conditions under which they obtain their phosphorous nutrition.

The results of our experiments on the residual effect of superphosphate show that the current ideas on the degree to which plants utilize phosphorous fertilizers should be reviewed and re-evaluated. The problem has been recently discussed by Soviet researchers Sokolov (11, 12), Dmitrenko (3, 4), and Chirikov (14).

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PHOSPHATE CONVERSION IN THE SOILS OF THE TATAR REPUBLIC

L. M. VOYKIN, Kazan State University

The effectiveness of phosphorous fertilizers is closely related to the conversion of their phosphorous compounds into forms more or less available to crops. A knowledge of the characteristics of P_2O_5 conversion in different soils is helpful in working out the most efficient methods of applying these fertilizers.

The older literature held to the notion of rapid retrogradation of phosphorous fertilizers added to the soil. This view was supported by a great many reports showing the high adsorption capacity of various soils with respect to phosphate ions (PO_4) and the low percentage of phosphorous fertilizer utilization.

The problem is now being reviewed in the light of the modern use of the radioactive isotope of phosphorus and methods of group calculation of phosphates. Sokolov's method of using P^{32} (15), judging by the literature (6, 12, 14, 16), shows that the amount of phosphates available to plants in different soils is expressed in much larger values than when determined by means of acid extracts. Use of this method (20) to investigate the conversion of phosphorous fertilizers has revealed that phosphates remain available to plants for a fairly long period of time in a number of soils (7, 9, 10, 21, 23, 24). Several investigators (9, 10, 22) have pointed out that the slight residual effect of phosphorous fertilizers is not due to retrogradation, but to the loss of essential nutrients (N, P, K), nitrogen in particular.

Experiments with Superphosphate

The soils of the Tatar Republic have been scarcely studied as far as the uptake and transformation of phosphorous fertilizers are concerned (4, 5, 13). To delve more deeply into he problems involved, we ran experiments on superphosphate and radioactive isotope P^{32}.

The first experiment included samples from he plow layers of ordinary and leached chernozems, dark-gray weakly podzolic, cinnamon-brown, gray weakly podzolic and sod-strongly podzolic soils. Air-dried 1 kg batches of soil passed through a sieve with openings 1 mm in diameter were placed in glass pans. Identical batches of the same soils were carefully mixed with finely ground superphosphate at the rate of 500 mg per kg of absolutely dry soil before being placed in the pans. As controls, soils fertilized with superphosphate were moistened with distilled water to 60% of the total moisture capacity and left at room temperature for about a year and a half. Water was supplied through the experiment. Samples were periodically taken from bare soils[1] and their content of the first three groups of phosphates (soluble in $H_2O + CO_2$, CH_3COOH, and HCl) determined by Chirikov's method with Shkonde's modification (23). The phosphoric acid of these groups was determined colorimetrically using a photoelectric colorimeter. Duplicate analyses were made at the following intervals: 24 hours, 1 month, 1 year, and 1-1/2 years after the start of the experiment. The results are presented in Table 1.

The data reflecting the dynamics of superphosphate phosphates in ordinary chernozem show that there was a decrease in carbonic acid-soluble phosphates throughout the period of composting. Within a day the amount dropped by 28% of the P_2O_5 added with the superphosphate. A further loss in this group of phosphates occurred in the course of time: after a month it was 39%, after a year 50%, and after 1-1/2 years 59% of the P_2O_5 of the added superphosphate.

Basic calcium phosphates (group 2) formed simultaneously with the decrease in carbonic acid-soluble phosphates. During the process of composting there was a continuous increase in the amount of these phosphates, reaching 47% of the P_2O_5 added with the superphosphate by the end of the experiment.

Sesquioxides (group 3) did not form during the initial period of superphosphate interaction with ordinary chernozem. Only after a year of composting were they found in the amount of 48 mg of P_2O_5 per kilogram of soil or $\sim$10% of the P_2O_5 added. This figure increased somewhat by the end of the experiment to 11% of the phosphoric acid of the fertilizer.

The dynamics of superphosphate conversion in leached chernozem is virtually the same as that in ordinary chernozem. Here, too, there

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[1] In all cases the samples were analyzed while the soil was moist.

Table 1

Changes in the amount of various groups of phosphates in nonfertilized and superphosphate-fertilized soils of the Tatar Republic, P_2O_5 in milligrams per kilogram of absolutely dry soil

Experimental treatment	Soluble in $H_2O + CO_2$				Soluble in 0.5 n CH_3COOH				Soluble in 0.5 n HCl				Total of soluble phosphates			
	Time of superphosphate interaction with the soil															
	24 hours	1 month	1 year	1-1/2 years	24 hours	1 month	1 year	1-1/2 years	24 hours	1 month	1 year	1-1/2 years	24 hours	1 month	1 year	1-1/2 years
Ordinary chernozem																
Control soil	42	41	40	39	347	254	202	210	41	81	110	111	430	376	352	369
Soil + superphosphate	401	364	288	244	545	473	405	446	66	124	213	260	1012	961	906	950
Formed from superphosphate and soil phosphates	359	323	248	205	198	219	203	236	25	43	103	149	582	585	554	590
Formed only from superphosphate	359	323	248	205	141	177	203	236	0	0	49	59	500	500	500	500
Leached chernozem																
Control soil	48	45	41	40	409	326	230	208	45	64	99	98	502	435	370	346
Soil + superphosphate	373	336	238	205	583	533	463	453	50	146	216	256	1000	1010	917	914
Formed from superphosphate and soil phosphates	325	291	197	165	174	207	233	245	5	82	117	158	504	580	547	568
Formed only from superphosphate	325	291	197	165	174	207	233	245	1	2	70	90	500	500	500	500
Dark-gray weakly podzolic																
Control soil	30	33	35	33	179	149	159	162	132	145	175	184	341	327	369	379
Soil + superphosphate	415	312	249	211	303	344	399	407	171	200	294	334	889	856	942	952
Formed from superphosphate and soil phosphates	385	279	214	178	124	195	240	245	39	55	119	150	548	529	573	573
Formed only from superphosphate	385	279	214	178	115	195	240	245	0	26	46	77	500	500	500	500
Cinnamon brown																
Control soil	82	69	47	45	308	338	362	380	158	167	179	187	548	574	588	612
Soil + superphosphate	334	297	241	185	493	539	574	599	233	274	339	388	1060	1110	1154	1172
Formed from superphosphate and soil phosphates	252	228	194	140	185	201	212	219	75	107	160	201	512	536	566	560
Formed only from superphosphate	252	228	194	140	185	201	212	219	63	71	94	141	500	500	500	500

							Gray weakly podzolic									
Control soil	57	55	52	49	117	124	68	109	156	160	163	178	330	339	283	336
Soil + superphosphate	392	314	194	158	250	284	291	347	215	258	346	387	857	856	831	892
Formed from superphosphate and soil phosphates	335	259	142	109	133	160	223	238	59	98	183	209	527	517	548	556
Formed only from superphosphate	335	259	142	109	133	160	223	238	32	81	135	153	500	500	500	500
							Sod-strongly podzolic									
Control soil	52	48	33	32	83	80	76	80	139	149	179	184	274	277	288	296
Soil + superphosphate	390	251	169	142	194	276	289	297	210	254	366	392	794	781	824	831
Formed from superphosphate and soil phosphates	338	203	136	110	111	196	213	217	71	105	187	208	520	504	536	535
Formed only from superphosphate	338	203	136	110	111	196	213	217	51	101	151	173	500	500	500	500

Table 2

Conversion of superphosphate P_2O_5 in certain soils of the Tatar Republic in relation to its length of interaction with the soil (P_2O_5 in milligrams per kilogram of absolutely dry soil)[a]

Soil	Time of superphosphate interaction with the soil															
	24-hours				1 month				1 year				1-1/2 years			
	Phosphate groups															
	I+II		III		I+II		III		I+II		III		I+II		III	
	P_2O_5	As a % of that applied	P_2O_5	As a % of that applied	P_2O_5	As a % of that applied	P_2O_5	As a % of that applied	P_2O_5	As a % of that applied	P_2O_5	As a % of that applied	P_2O_5	As a % of that applied	P_2O_5	As a % of that applied
Ordinary chernozem	500	100	0	0	500	100	0	0	451	90	48	9	442	88	58	11
Leached chernozem	498	99	1	0	498	99	2	0	430	86	69	14	410	82	90	18
Dark-gray weakly podzolic	500	100	0	0	474	94	25	5	453	90	46	9	423	84	77	15
Cinnamon-brown	437	87	62	12	429	85	70	14	405	81	94	18	359	71	140	28
Gray weakly podzolic	467	93	32	6	419	83	80	16	365	73	134	26	347	69	152	30
Sod-strongly podzolic	449	89	50	10	399	79	100	20	350	70	150	30	327	65	173	34

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[a] P_2O_5 added with superphosphate, 500 mg/kg of soil.

was a steady decrease in group 1 phosphates. The loss of carbonic acid-soluble phosphates amounted after a day to 35%, after a month to 42%, after a year to 60%, and after 1-1/2 years to 67% of the amount of P_2O_5 added with the superphosphate.

The content of group 2 phosphates grew throughout, rapidly at first, slowly after a year. By the end of the year of superphosphate interaction with leached chernozem the content of basic calcium phosphates (group 2) was 46% of the amount of P_2O_5 added.

Group 3 phosphates scarcely formed after one month of superphosphate interaction with leached chernozem. The amount rose markedly by the end of the year to 18% of the P_2O_5 added with the fertilizer.

The quantitative conversion of superphosphate P_2O_5 in dark-gray weakly podzolic soil is about the same as in the chernozem soils. Carbonic acid-soluble phosphates during the period of superphosphate interaction with this soil decreased to about the same extent as in the chernozems. By the end of the experiment the content decreased to 35% of the P_2O_5 in the superphosphate.

The dynamics of the group 2 phosphates in the dark-gray weakly podzolic soil reflected a picture similar to that in the chernozems. There was an increase in the amount of group 2 phosphates throughout the period of composting, but the rate decreaced markedly after a year.

Sesquioxide phosphates (group 3) in the dark-gray weakly podzolic soil formed in about the same amounts as in the chernozems, but the process began much earlier. After a month they constituted 5% and by the end of the experiment 15% of the phosphoric acid in the fertilizer.

The noteworthy thing about the conversion of superphosphate in the cinnamon-brown soil was the sharp decrease in carbonic acid-soluble phosphates during the initial period of interaction caused by the increased sesquioxide content of this soil. The rate of loss of this group of phosphates later slowed up. The initial decrease was about 50%, after a month 54%, after a year 61%, and at the end of the experiment 72% of the P_2O_5 added with the superphosphate.

The decrease in group 1 phosphates in the cinnamon-brown soil was accompanied by the formation both of basic calcium phosphates (group 2) and sesquioxide phosphates (group 3) from the superphosphate. The sesquioxide phosphates appeared at the very beginning and increased steadily with time. The formation of group 2 phosphates ended mostly within a month of the interaction and then proceeded very slowly. They amounted at that time to 40% and, at the end of the experiment, to 44% of the P_2O_5 of the superphosphate.

Group 3 phosphates in the cinnamon-brown soil amounted to 63 mg of P_2O_5 per kilogram of soil during the first few days. After a month they came to 71 mg and, at the end of the experiment, to 141 mg per kilogram of soil, or 28% of the phosphoric acid added.

In the gray weakly podzolic soil the amount of carbonic acid-soluble superphosphate phosphates during fallow decreased more rapidly, and at the end of the experiment only 22% of the P_2O_5 added remained. At the same time basic calcium phosphates (group 2) and sesquioxide phosphates (group 3) formed. The increase in group 2 phosphates ended after a year of interaction and thereafter virtually came to a halt. At the end of the year they amounted to 223 mg and by the end of the experiment increased by 15 mg of P_2O_5 per kilogram of soil.

The formation of group 3 phosphates from superphosphate started from the moment of interaction with the gray weakly podzolic soil and continued throughout the experiment. The amount after a day was 32 mg (6%), reaching 153 mg of P_2O_5 per kilogram of soil, or 30% of the phosphoric content in the superphosphate, at the end of the end of the experiment. During the composting period the group 3 phosphates formed in this soil from the superphosphate increased almost fivefold.

The sod-strongly podzolic soil exhibited a continuous loss of carbonic acid-soluble superphosphate phosphates, amounting at the end of the experiment to 110 mg of P_2O_5 per kilogram of soil, or 22% of the P_2O_5 of the superphosphate. The decrease in this group of phosphates resulted in the formation of group 2 and group 3 phosphates. The new formation of calcium phosphates (group 2) largely ended after a month of superphosphate interaction with the soil, amounting to 196 mg of P_2O_5 per kilogram of soil. Group 2 phosphates subsequently formed very slowly and came to 217 mg at the end of the experiment owing to the low total of exchangeable bases in this soil.

The new formation of sesquioxide phosphates (group 3) took place throughout the period of superphosphate interaction with the sod-strongly podzolic soil. At the end of the experiment the total amount of 173 mg of P_2O_5 per kilogram of soil, or 34% of the amount added with the superphosphate.

The investigations of Chirikov (22) and Shkonde (23) suggest that the first two groups of phosphates are the main source of phosphates in a form available to crops. They classify the sesquioxide phosphates with the less available forms. It is interesting in this connection to study the amount of superphosphate P_2O_5 remaining in a plant-available form in the soils under investigation. The materials presented in Table 2 are instructive. They show quantitative changes in the total of group 1 and group 2 phosphates, the group 3 total being given separately. In the chernozems, and the dark-gray weakly podzolic soils resembling them, it appears that the superphosphate phosphates remain virtually intact for a long time in a form available to plants (total of groups 1 and 2), amounting after a month of interaction to almost 100% of the phosphoric acid added with the superphosphate. With time the content of the most available forms of phosphorus (groups 1 + 2) decreases somewhat, reaching 82%-88%

of the P_2O_5 added to the soil by the end of the experiment. The sesquioxide phosphates (group 3) do not form at the beginning of the interacion in chernozems and they increase only with ime, amounting to the end of the experiment o 11%-18% of the phosphoric acid added with he superphosphate.

In studying the dynamics of superphosphate phosphates in podzolic soils — from the cinnamon-brown to the sod-strongly podzolic — we were struck by the more pronounced decrease n the available forms of phosphorus and the rather rapid formation of the less soluble phosphates at their expense. Thus, the total of group 1 and group 2 phosphates during the first ew days increased 6%-12%; with lengthening of the time of composting they continued to decrease steadily and at the end of the experiment ranged from 65%-71% of the P_2O_5 added with the superphosphate.

The sesquioxide phosphates (group 3) began o form in these soils from the moment the experiment was set up, and they increased with ime, amounting at the end of the experiment o 28%-34% of the P_2O_5 of the superphosphate, or almost double the total in the chernozem soils. This suggests that in podzolic soils the process of converting superphosphate P_2O_5 into forms virtually unavailable for plants takes place more rapidly than in chernozem soils.

This phenomenon is due to the presence in podzolic soils of smaller quantities of exchangeable alkaline-earth bases and to their comparaive enrichment with the hydrates of sesquioxides fixing the P_2O_5 of the added superphosphate in the form of sesquioxide phosphates. However, fertilizer P_2O_5 is not fully converted nto forms of phosphates unavailable to plants n podzolic soils either; a fairly substantial amount remains in an available form for a long ime.

Experiments with the Radioactive Isotope of Phosphorus

To check our findings, we ran experiments on the dynamics of forms of phosphates using he radioactive isotope of phosphorus (P^{32}). We used a solution of radioactive KH_2PO_4, saturating he soils in accordance with Bogdan's method (3). Air-dried 100 g batches of different soils from he Tatar Republic were placed in porcelain breakers to which 30 ml of radioactive KH_2PO_4 solution had been added. The specific activity of the solution was 4.0 μCu, total 121.5 μCu. The beakers were covered with a watch glass and left at room temperature; average soil samples were obtained for analysis one month and one and one-half months after start of the experiment. The samples were air dried before undergoing analysis. The P^{32} was leached from the soil by Shkonde's method (23) involving he use of 0.06 n $H_2O + CO_2$, 0.5 n CH_3COOH, and 0.5 n HCl. Five milliliters of each filtrate were placed in small porcelain crucibles and evaporated on an Eternit hot plate until dry after which we counted the activity in impulses/minute with a B-type apparatus. The results (Table 3) show the forms of phosphorous compounds entered by the P^{32} while interacting with different soils. In an ordinary leached chernozem and similar dark-gray weakly podzolic soil half of the P^{32} remains in a carbonic acid-soluble form (46%-49%). More prolonged contact of P^{32} with chernozems scarcely affected the amount passing into the carbonic acid extract. The carbonate chernozem is an exception. The amount of P^{32} remaining in carbonic acid-soluble form proved to be somewhat less than in ordinary and leached chernozems, and with time it decreased even more. This phenomenon is apparently due to the fact that the carbonates of alkaline-earth bases present in this soil are responsible for its high buffer resistance to weakly acid solutions like $H_2O + CO_2$, so that a stronger solvent is required to dissolve the phosphates of the alkaline-earth bases formed. It is also the obvious reason why more P^{32} is found in acetic acid and hydrochloric acid filtrates from the carbonate chernozem than from the ordinary and leached chernozems.

Soils of the podzolic group contain less P^{32} in carbonic acid-soluble form (18%-32% of the total content) and this amount decreases with time, which indicates that it is gradually con verted into other, less soluble phosphoric-compounds.

The acetic acid extract shows that when P^{32} interacts with soils for a month it forms basic calcium phosphates (group 2) in equal amounts in all the soils. It is only in the most podzolized soils that there is somewhat less P^{32} entering into this group of phosphorous compounds, constituting 23%-30% of the total content. With the passage of time the interaction of P^{32} with soil slows up its movement into the acetic acid extract without changing, however, its quantitative relationships in the different soils.

Sometimes more than two or three times as much P^{32} goes into an hydrochloric extract from podzolic soils than from chernozems (47% against 14% in chernozems). Lengthening the composting period increases the amount of P^{32} forming compounds with R_2O_3; this process is somewhat more pronounced in podzolic soils than in chernozems.

Table 4 shows the distribution of P^{32} in soils of the Tatar Republic arranged by groups in terms of availability to plants. It presents the percentage of the total of group 1 and group 2 phosphates (most available to plants) and group 3 (virtually unavailable to plants) phosphates separately. The data reveal that P^{32} in chernozems and the similar dark-gray weakly podzolic soil remains available to plants in substantial quantities. In gray and light-gray podzolic soils amost 50% of it forms compounds with the sesquioxides, i.e., phosphorous compounds less available to plants. The amount of P^{32} interacting with the sesquioxides in podzolic soils is more than double that in soils of the chernozem group.

The interaction of P^{32} with soil gradually decreases the amount remaining in a condition available to plants so that it is more readily converted into the sesquioxide forms of phosphates.

Thus, the results of the experiments with P^{32} supported our findings based on the conver-

Table 3

Conversion of the radioactive isotope of phosphorus (P^{32}) while interacting with the soils of the Tatar Republic[a]

Soil	Total amount of displaced P^{32}, counts/min		Phosphate groups as a % of the total					
			I		II		III	
	1 month	1-1/2 months	1 month	1-1/2 months	1 month	1-1/2 months	1 month	1-1/2 months
Ordinary chernozem	3328	1484	47	50	37	29	16	21
Leached chernozem	3244	1439	47	49	39	29	14	22
Carbonate chernozem	3074	1403	36	27	35	34	29	39
Dark-gray weakly-podzolized	3454	1507	41	47	38	27	21	26
Cinnamon-brown	3376	1523	36	33	37	30	27	37
" "	3412	1439	19	23	33	24	48	53
Gray weakly podzolic	3268	1487	21	17	37	28	42	55
Gray moderately podzolic	3487	1494	32	23	23	28	45	49
Light-gray weakly podzolic	3445	1441	24	17	29	24	47	59
Sod-strongly podzolic	3567	1525	31	26	30	26	39	48

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[a] The activity in counts/minute is shown for the day of each determination without conversion to the day the experiment began or ended.

Table 4

Distribution of P^{32} in the soils of the Tatar Republic by phosphate groups as a % of the total[a]

Soil	Time of P^{32} interaction with the soil					
	1 month			1-1/2 months		
	Total amt. of P^{32} displaced, counts/min	I+II	III	Total amt. of P^{32} displaced, counts/min	I+II	III
Ordinary chernozem	3328	84	16	1484	78	22
Leached chernozem	3244	85	15	1439	78	22
Carbonate chernozem	3074	71	29	1403	61	39
Dark-gray weakly podzolized	3454	79	21	1507	74	26
Cinnamon-brown	3376	73	27	1523	63	37
Gray weakly podzolic	3412	52	48	1439	47	53
Gray weakly podzolic	3268	58	42	1487	45	55
Gray moderately podzolic	3487	56	44	1494	51	49
Light-gray weakly podzolic	3445	53	47	1441	41	59
Sod-strongly podzolic	3567	61	39	1525	53	47

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[a] The activity in counts/minute is shown for the day of each determination without conversion to the day the experiment began or ended.

sion of superphosphate phosphates.

Conclusions

1. Laboratory research on the conversion of superphosphate in the main soils of the Tatar Republic showed that the P_2O_5 of fertilizer when interacting with soil produces not one but several groups of phosphorous compounds differing in degree of solubility and, consequently, availability to plants.

2. In composting superphosphate with soil amount of carbonic acid-soluble P_2O_5 de-ases irregularly throughout the period of eraction.

3. The formation of basic calcium phos-tes (group 2) from superphosphate and ses-oxide phosphates (group 3) proceeds simul-eously with a decrease in carbonic acid-uble phosphates. The amount of these phos-tes is determined by the genetic group of soil. In chernozems the basic mass of bonic acid-soluble phosphates is converted group 2 phosphates; only an insignificant t is converted into group 3 phosphates. re than twice as much group 3 phosphate is med in podzolic soils than in chernozems, ng to both the presence of comparatively ge quantities of nonsilicate forms of sesqui-des and the low content of exchangeable al-ine-earth bases.

4. While interacting with the soil, super-sphate increases the solubility of soil com-nds of phosphorous. In chernozems this pens because of the increased solubility of cium and sesquioxide phosphates; in pod-ic soils, however, it is largely the result ncreased solubility of the sesquioxide phos-tes.

5. In soils of the chernozem group the bulk superphosphate P_2O_5 (about 82%-88%) re-ins for a long time in a form available to nts and only a trifling amount (12%-18%) s into the formation of barely soluble phos-rous compounds. In podzolic soils twice as ch barely soluble phosphate (group 3) is med from superphosphate P_2O_5 than in cher-ems (28%-34%). However, in these soils, , the amount of plant-available phosphorous ning from superphosphate is sustained at a h level (65%-71%).

6. Rapid retrogradation of phosphorous fer-zers in soils with the conversion of their $_5$ into a farm unavailable to plants did not ur. Thus, the proper time to add phosphor- fertilizers to soils of the chernozem group s not seem to be particularly important.

The results of our experiments on super-sphate conversion and the published ma-ial suggest that the main factor responsible the slight residual effect of phosphorous tilizers on the soils of the Tatar Republic ot their retrogradation, but disturbance of ratio of the principal nutrients (N, P, K) re-red by the crops.[2]

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CCURACY IN MAPPING SOILS FROM AERIAL PHOTOGRAPHS

A. PLATONENKO, S. M. Kirov Omsk Agricultural Institute

The main task of agriculture during the next ven years is to increase the production of ain and forage crops in every possible way. is calls for the kolkhozes and sovkhozes to ke proper use of crop rotations with due re- rd for the climatic and economic conditions evailing in the different zones of the USSR. tensive soil, chemical, geobotanical, and ier investigations will have to be made.

The existing soil maps, even large-scale ps, generally do not reflect the variegation the soil mosaic. The need of detailed maps a fairly large scale for the forest steppe of stern Siberia is particularly evident because soil is extremely complex.

The methods of mapping soils currently em- yed are far from perfect. They do not have accuracy and detail associated with the rticular scale of the map. It is only in con- ction with very large-scale maps (1:2000) t a dense grid system is used and the soil ındaries are determined therefrom with fair curacy.

Soil survey differs from other types of sur- in a number of respects. The soil scientist ps the invisible contours from the surface. e boundaries of soil contours are very wavy, fuse, and fuzzy so that they cannot be traced oughout their length. Thus the accuracy and ail of the maps become subjective.

When individual contours cannot be repre- ted on a map of a given scale owing to their eness and to variegation of the soil, the pper uses symbols to indicate the complexity. he plains of Siberia the nature of the con- rs on the map does not emphasize the sence of many small depressions and eleva- ns so that errors in determining the degree complexity are likely to be large. It often pens that the visibility of a locality is so r that the soil scientist is simply unable to tinguish the fine contours which might be presented on a given scale. Our field checks soil maps has shown that in many cases soil tours embracing an area of 3-5 cm² on a p were included within the complex.

A solution of the immense tasks outlined in Seven Year Plan requires, to begin with, a ailed description of each boundary line of icultural lands as well as of their parts. The scope and significance of soil investigations in the elaboration of methods to increase soil fertility will grow year by year. Thus the symbols used on soil maps will have to be held to a minimum. We believe that the smallest contour area now distinguishable on maps (1 cm², according to instructions), should be reduced to 10 mm².

The quality, accuracy, and detail of soil mapping can be improved only by the use of aerial methods. These methods, particularly photomaps, have been of interest to soil scientists for some time. The very first time they were used revealed their great potential value in photographic representation of the earth's surface. A photographic emulsion transmits the entire range of shades found in nature. Even an ordinary photograph with all the limitations of black and white can reflect not only different soil groups but also subgroups. A major weakness of black-and-white photography is the inconsistency of tonal shades for identical soils. However, within a single traverse, frequently within the entire area photographed in the course of a single day, the tonality of similar soils is so regular that they can be identified in the office after just a little field work. The value of office interpretation is enhanced by stereoscopic examination of the photographs.

Interpretation is immeasurably improved by color and spectrozonal aerial photography, which is now coming into use. The technique involved is still very complicated and is scarcely beyond the trial-and-error stage.

Various geographical zones have already been photographed. Most of the investigators (1, 3, 4, 6, 7, 9, 10) consider the resultant maps more useful than those produced by plane-table surveys. On the other hand, Sadovnikov (8) does not consider them superior to topographic maps for cultivated soils. Unfortunately, he doesn't cite any specific examples to support his conclusion, which in any case could hardly apply to all cultivated soils.

Photomaps are far better than any topographic maps in richness of contour content, detail, and accuracy in reflecting shades that are sometimes even imperceptible to the eye. This detail is particularly necessary for plains regions where the nature of the contours does not emphasize the microrelief, thus requiring laborious measurements for representation of spottiness of soils.

Methods of using photomaps have now been developed (1, 2, 6, 9) for different zones. They involve essentially establishment of direct and indirect interpretation signs to reflect on the maps of a given flight terrain details, primarily those of the vegetation and soil types. These signs are used on key areas most characteristic of the object to be mapped. The resultant standards become the basis for interpreting the other soils in the area under investigation. The soil samples taken and boundary lines plotted in the office are subsequently checked in the field and adjusted to actual conditions wherever errors of interpretation have been made.

The need of field control of the delineating boundaries, especially if the soils are similar, is evident in mapping cultivated areas. The crops hide the ground and make representation of the soil contours difficult. That is why most investigators (1, 2, 3, 6, 10) recommend early spring or late fall, when the ground is bare, as the time to do the mapping. The opportunities for office interpretation are thus greatly improved. This recommendation is in line with the requirements of photogrammetry (for accuracy in relief drawing by stereomethods), but it is impractical because there are no more than twenty to thirty good flying days per season in the temperate latitudes, and most of them come in the summer.

In mapping soils attention must be focussed on the materials obtained for general topographic purposes by aerial surveys made throughout the summer. Detailed maps for devising suitable management practices are particularly necessary in connection with developed lands. Areas lacking in natural vegetation reflect fairly well a wide range of soil shades on maps.

The use of aerial photographs for soil studies is exceptionally timely because "agricultural aerial survey" organizations have embarked upon an extensive program of inspection of agricultural lands with simultaneous interpretation. The copious descriptive data produced by this work is a valuable aid in revising old soil maps as well as a basis for compiling more detailed and much more accurate large-scale maps. We ought to combine the efforts of map interpreters and soil scientists, assigning some of the latter from the land-use administrations to the "agricultural aerial survey" organizations. There should be at least one soil scientist in every geodetic unit engaged in this work as against the present ratio of one to every four or five units.[1]

A major problem of cartography is accuracy in plotting the objects to be mapped. Accuracy in inserting the soil boundaries is unusually important because the position of boundary lines is fairly permanent. Hence an accurate map could be useful for quite a few years. According to Maslov (5), the accuracy of soil survey maps on a scale of 1:10, 000 was ±31-47 m, or 3.1-4.7 mm on the map. These errors resulted from plotting the soil boundaries by interpolatio between soil profiles, taking into account the relief of the locality represented on the map by contours. Maslov attributes this low accuracy to indistinctness of the boundaries, which prevents the eye from detecting the abrupt transition of one soil into another. Official instructions allow for errors ranging from 2-8 mm in plotting the soil contours between 1:10, 000 to 1:25, 000 topographic maps depending on the difficulty in delineating the boundaries. This means 20-80 m on the ground for maps on a 1:10, 000 scale and 50-200 m for maps on a 1:25, 000 scale.

The use of such maps in planning the organization of the land within a single farm often results in including areas with unsuitable soil in the field of a crop rotation. This is illustrated by the following simple calculations. If we assume that the area of a field in a crop rotation is 100 ha (1 km x 1 km) and that the position of the soil boundaries is determined with a mean error of ±50 m, the field will include about 5 ha of land with unsuitable soil, or 5% of the area of the field.

We feel that the accuracy of soil maps must match that of land-use plans and be no cruder in the insertion of topographic contours with indistinct boundaries. The maximum error in plotting soil boundaries should be no more than ±2 mm on the map. This accuracy can be achieved by using aerial photographs. Our worl in mapping solonetz soils in the forest steppe of Western Siberia enabled us to ascertain the tonal qualities of the soil and improve the accuracy of our mapping.

The forest-steppe zone of Western Siberia is characterized by a variegated soil. The presen of many small depressions alternating with microelevations against a general background o plains relief is responsible for the abrupt trans tion from one soil type to another. For exampl weakly solonetz soils frequently alternate with crustal solonetzes within two or three meters o medium- and high-columnar solonetzes. Solods and gray forest solodized soils are found mainl in and near forested areas. Ordinary and solonetzic chernozems are common on the mos elevated portions of the relief.

The tonal coloring of the soil on photomaps depends largely on the humus content of the uppermost horizon. When the ordinary method of plowing has been used, the photomaps clearly reveal shallow solonetz and solodized types, which are white or whitish in tone. However, the strongly solodized crustal solonetzes are difficult to distinguish from the solods by tone. This requires on-the-spot inspection. Deep solonetzes and solonetzic soils show up light gray or gray on maps, depending on the humus content. Forest-steppe chernozems with moderate humus content of 7%-8% appear dark gray.

Geodetic field work was undertaken on plowe and virgin strips to ascertain the possibility of

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[1] The Department of Geodetic Aerial Photography, S. M. Kirov Omsk Institute of Agriculture, in cooperation with the Department of Soil Science has been investigating for a number of years the possibility of utilizing aerial photography for soil mapping.

Table 1

Errors in office identification of soils by phototone

Error indices	Scale of aerial photographs					
	1 : 5000		1 : 10 000		1 : 17 000	
	plow-land	Virgin land	plow-land	Virgin land	plow-land	Virgin land
Standard deviation, mm	0,64	1,06	0,35	0,56	0,24	0,44
On the ground, m	3,2	5,3	3,5	5,6	4,1	7,5
Maximum, mm	1,2	1,9	0,8	1,0	0,5	0,7
On the ground, m	6,0	9,4	10,0	8,5	8,5	11,9

lote: Comma represents decimal point.

pping the soil from the tonal coloring of
otomaps of various scales and of determining
accuracy in plotting the soil boundaries
m the phototone. The distance between con-
r points whose position was accurately de-
mined on aerial photographs was measured
the ground with a 20-meter steel tape. A
eat number of borings were made along a
e 500-700 m long taking into account changes
the microrelief and vegetation, which en-
ed us to distinguish in detail all the soil dif-
ences. Thus, the position of all soil
ndaries intersecting the line was accurately
ermined by measurement. The line direc-
n was fixed so as to allow the maximum num-
of soil contours to intersect. The availa-
ity of good quality aerial photographs on a
le of 1:17,000 (taken early in July 1957) re-
rded on a panchromatic emulsion facilitated
task.

Contact prints enlarged to a scale of 1:10,
) and 1:5,000 were made from the negatives
ascertain the accuracy of the maps and to
ermine the usefulness of enlargements. The
ct value of the scale was determined from
distances measured on the ground along the
e between the contour points.

A soil map compiled on a scale of 1:25,000
ortunately does not show many soil contours,
l they are included in a complex even if the
e is above the minimum for the particular
le. It is therefore senseless to compare
h a map with the representation of contours
aerial photographs. Accuracy can be
ged only by comparing the position of soil
tours on photomaps and on the ground. Ac-
dingly, we drew lines (Figs. 1 and 2) on
h photograph (1:17,000, 1:10,000, and 1:
00) between the recognizable contour points
in the office identified by the phototone the
boundaries crossing the lines. We then
asured the distances from one contour point
the photographs of all the scales to the
ndaries of the contours distinguished in the
ce. Errors in locating the boundaries were
ermined from the difference between the
tances measured on the photographs and on
ground. The results are summarized in
le 1.

Table 1 shows that the absolute magnitude of
error in distinguishing soil boundaries by
totone has scarcely any relationship to the scale of the photomaps. For example, the standard deviation in distinguishing soils on plowland with over triple magnification of the scale changed from 4.1 to 3.2 m.

A comparison of our values with those obtained by Maslov (5) shows that our accuracy was ten times as great. Thus, aerial photography permits a significant increase in the accuracy of plotting the boundaries of soil contours.

Errors in distinguishing soil contours on virgin land (pasture) were somewhat greater with a reduction in the scale of the photomaps (5.3-7.5 m). This is due to the fact that the vegetation on shallow solonetzes dies out by mid-June, thus preventing reliable identification of the soil contours by the phototone. The maximum error in plotting the boundaries on the photomaps did not exceed ±1.2 mm, which convinced us of the soundness of our recommendation that the maximum error in plotting soil contours on photomaps should be 2.0 mm.

A close study of aerial photographs showed that similar soils cannot be distinguished by the tone. For example, high- and medium-columnar solonetzes have an identical tone. It is very easy to discern crustal solonetzes, which have a whitish, reticular pattern with broken borders on photographs. Portions of solods emerging from under forests are white with smooth borders.

The forest-steppe zone reveals a fairly regular pattern of alternation of soils occasioned by changes in the microrelief. This circumstance can be effectively used as an indirect feature in mapping transitional soils not distinguishable by the phototone.

The freedom from error in distinguishing soil contour boundaries on the ground and the scale of the photographs makes it possible to utilize a wide range of scales of flights for soil mapping. However, in addition to accuracy, a given scale of map calls for attention to the detail. Therefore, in working with contact prints their scale must be chosen by analogy with aerial photography where the scale of the flight should not be smaller than 1 1/2 - 2 times the scale of the map to be issued.

We have further discovered in working with

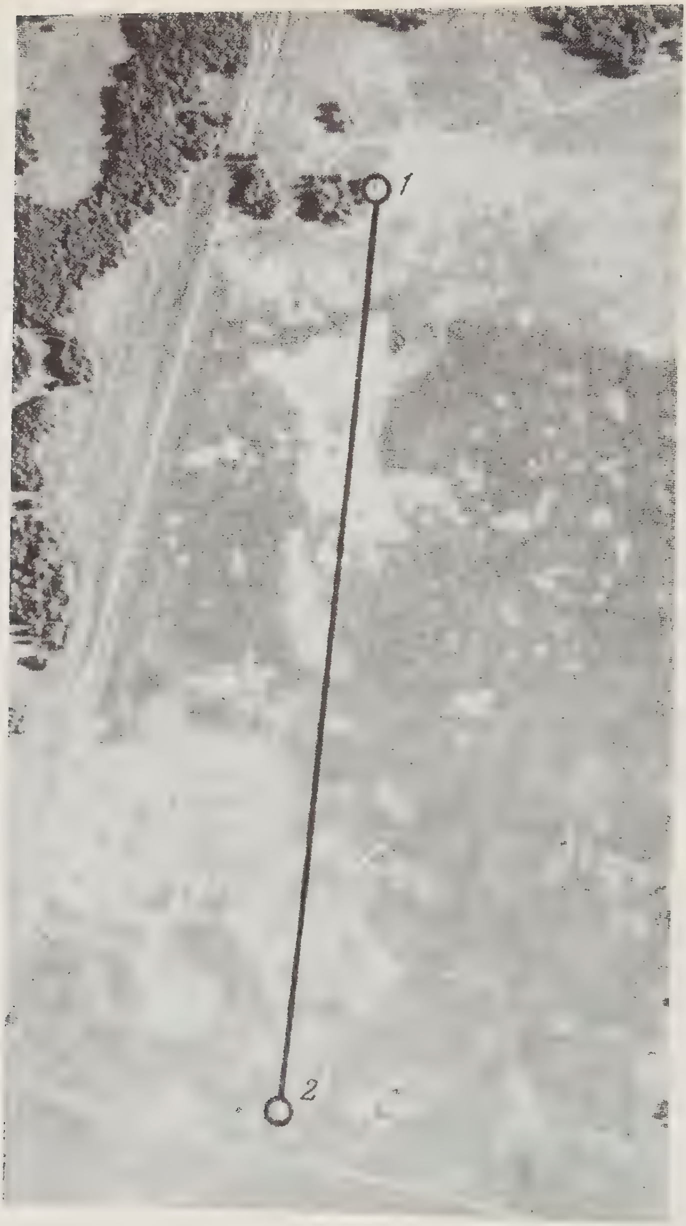

Fig. 1. - Enlarged aerial photograph, scale 1:5000. 1-2-line between contour points.

with photographs enlarged 3-5 times that the loss of definition and optical resolving power does not particularly complicate the task of mapping soils. Thus mapping the soils of experimental plots and other objects from photographs enlarged to a scale of 1:20,000 would seem to be very promising. In view of the limited size of the plots, it is quite obvious that special flights on the scale of say 1:2,000 or 1:5,000 would not be worthwhile. Hence mapping these objects on enlarged photographs is the only possible method.

Photographs of various scales also make it possible to reflect in varying degree details of objects to be mapped. The larger the scale, the smaller the size of the contours capable of being reflected on the photograph. We learned that the smallest contour that could be shown on a photograph was 0.5 mm wide. For the various scales this corresponds on the ground as follows 1:17,000 - 8.5 m; 1:10,000 - 5.0 m; 1:5,000 - 2.5 m. Therefore, to establish the conventional mapping detail, it is necessary to take as the original the quantity of contours capable of being

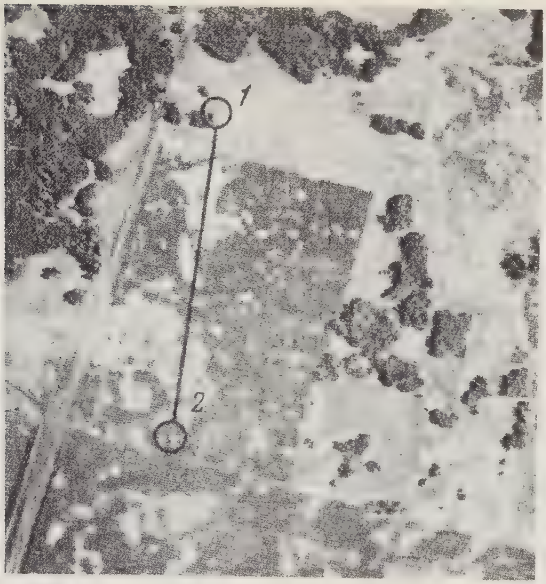

Fig. 2 - Contact print, scale 1:17,000
1-2 - line between contour points.

own on a given scale. By conventional map- ng detail we mean the ratio of the number of ntours shown to the original number for the ven scale.

Table 2

Size of soil contours on the ground

Width of contours, m	Number of contours	
	Plowland	Virgin land
Up to 2,5	3	—
2,6 – 5,0	14	3
5,1 — 8,5	7	—
Above 8,5	45	16
Total	69	19

Note: Comma represents decimal point.

The size of the soil contours intersected by lines on the ground is shown in Table 2. It is easy to calculate from this table the number of contours that can be shown on photographs of different scales. Our calculations revealed that the largest number of contours both on plowland and on virgin land was discerned on enlarged aerial photographs on a scale of 1:5,000. It turned out that changing the scale had no significant effect on the detail, which averaged 70%-75% for plowland and 40%-45% for virgin land (Table 3). It is evident that the detail was greater on the former than on the latter. This finding applies to complex solonetz soils, plowed but without the columns being turned over.

The method of drawing lines that we used to determine mapping accuracy can be recommended for field study of the nature of vegetation and soil representation by phototone. Two or three lines 500-700 m long is the most typical places in the area being mapped constitute a standard for office mapping of 60%-70% of the area under investigation. The soil boundaries

Table 3

Conventional detail in mapping soils on aerial photographs of different scales

Scale of aerial photograph	Plowland			Virgin land		
	Initial contours	Shown on the photograph	% of detail	Initial contours	Shown on the photograph	% of detail
1 : 5 000	66	47	71,2	19	10	52,6
1 : 10 000	52	42	80,7	19	9	47,4
1 : 17 000	45	36	80,0	16	7	43,8

are traced in the office from the standard by comparing the phototone with the help of a stereoscope.

The best results are achieved with the basic materials of aerial photography — contact prints. Even negative maps with contour lines or reproductions from them do not preclude, indeed they enhance, the possibility of using contact prints. The defects of contact prints — limited visibility, numerous adjustments — can be easily overcome by photomontage.

It is necessary to have uninterpreted photos for mapping soils. The results of mapping soils are transferred from the hpotos to the map or base by ordinary photogrammetric methods.

The use of aerial photographs for soil mapping not only facilitates the work, but also promises to improve the accuracy and detail of the maps, save government funds, and increase the efficiency of personnel.

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A NEW MODEL OF A SMALL SOIL SAMPLER

. F. NEGOVELOV, North Caucasus Zonal Scientific-Research Institute of Horticulture and iticulture, Krasnodar

Design of the Drill and its Operation

The sampler is designed for sampling to a naximum depth of three meters under normal onditions and as deep as 5-10 m when the soil nd parent material are loose. It is an impact ype of sampler for determining morphologic eatures of the soil, i.e., for soil surveys, or soil moisture samples and for bulk density, s well as for chemical analyses. An average f 12-15 two-meter, or three-meter-deep holes an be made with this sampler a day. The ampler was tested at the Krasnodar Machine-esting Institute as a tool for taking soil amples to determine their moisture content nd proved to be more easy to use, have a igher rate of sampling and give results of etter quality than other similar samples. The ate of sampling during the tests was 10-11 inutes for a hole 2 m deep. The main adantage of this sampler, as compared to other and-operated samplers, is not only its high peed and ease of operation, but also the fact at in many cases it proved to be much more ccurate.

Principle of the Sampler. A soil sample is ut and separated from the lower layers by eans of a conical tip, each small section of hich represents a wedge placed at a certain ngle to the cut soil sample.

Figure 1 shows the principal working scheme the sampler. As can be seen, the inner surce of the conical tip forms an angle α with e surface of the cut sample. Thus, the conil tip comes into contact with the sample only ith its cutting edge (in Point A, as shown on ig. 1). There is no friction of the soil sample ainst the inside sampler and only a little dermation at the moment of cutting. It was dermined experimentally that under average il conditions the angle α should be 2.5-3°. r more or less dry soils this angle can be naller (but not less than 2°) and for moist ils it should be larger (about 4°). With naller or larger angles the sample is subject more deformation.

While sampling, the outer surface of the nical tip exerts considerable pressure on the il. The operator of the sampler must apply rce to move the outer soil and also to overme the friction between the tip and the soil.

The smaller is angle β the less is the danger that the sample be deformed, but the greater is friction (with the same hole diameter). Sampling gives satisfactory results when angle β is within the range of 8-12°. For construction reasons we selected an angle of 11°.

When the sampler is removed from the soil, the sample breaks off from the underlying layers because certain pieces of soil become wedged at angle α between the surface of the sample and the wall of the tip.

The given information has been checked in the course of extensive work with the sampler under different soil conditions.

Design of the Sampler (description of its parts). Since the mass production of samplers is not as yet adequately organized, we are enclosing detailed drawings and instructions on the base of which this sampler can be made in any ordinary mechanical shop (Fig. 2).

The list gives the most desirable materials for making such a sampler. The most difficult problem is to select the proper material for the shafts. If a 65 g spring steel smaller than 14-12-10 mm in diameter must be used, the size of the tip tube should remain unchanged, all other connections should be adjusted to the shafts, retaining, if possible, the dimensions of the connecting grooves — M 12[1] and a spacing of 1.75. Should this steel be unavailable, any other sufficiently hard spring steel can be used, for instance, U-10 or construction steel U-45[2], without reducing the diameter. The shafts do not need to be heat treated. The conical tip can be made of other steels and then hardened, or case-hardened. The scoop can be made not only of a GOST 1018-51 brass ribbon, but also of galvanized iron, white tin-plate, etc. The other parts of the sampler can be manufactured not only of Steel 40 but also of other kinds of steel with similar qualities.

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[1] M-12 and 1.75 refer to the diameter of the groove and the spacing of grooves in the metric system.

[2] U-45 is a brand of steel.

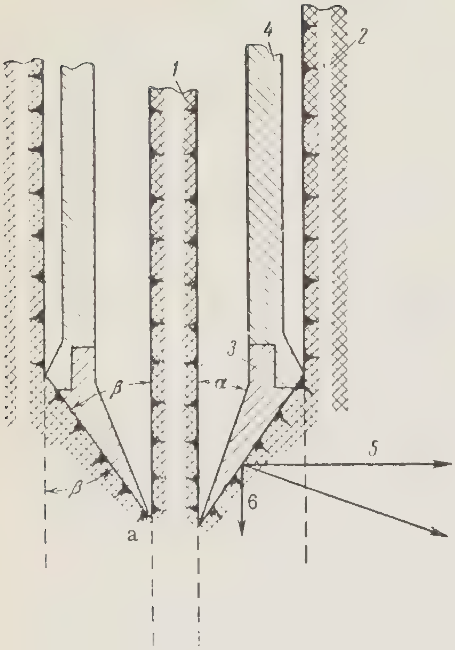

Fig. 1. - Outline of the sampler when it is driven into the soil.

1 - soil sample being cut; 2 - compacted side of the hole; 3 - a cross-section of the cutting tip $<\alpha = 2.5^{\circ}$ is the angle between the surface of the sample and the inner surface of the tip. $<\beta = 11^{\circ}$ is the angle at which the outer surface of the cutting tip comes in contact with the soil; 4 - sampler tube; 5 and 6 - the parallelogram of the distribution of forces when the sampler is driven into the soil.

The figures give a general view of the sampler and technical drawings of its parts from which it can be manufactured. Some of the most simple parts are not included. Most of the details are clear to shop mechanics from the drawings alone, and only a few of them need clarification.

A mark in the form of a point is made on the conical tip to indicate the position of the scoop in the tube. This point and its size are clearly shown on Figure 2b-1. The same drawing also shows part 2, which is the scoop which is soldered to the tip for which there is no separate drawing. Parts 3, 4 and 6 are not shown in cross-section through the slot for the wrench. The slot is the same as for part 1, which is shown in cross-section. Only one of the three shafts is shown. The other two, parts 7 and 8, differ from it in that they measure 1,000 mm in length and that the mark and numbers for reading the depth to which the sampler is driven into the soil are in a different position. Some of this can be seen in the general drawing of the sampler. There are no separate drawings for the head and the handle. Their outside dimensions are given in the general drawing. The inside dimensions of the opening and grooves are the same as for part 4, the connecting piece. The opening and groove of part 11, the spear-shaped solid tip are of the same dimensions. When the sampler is manufactured in an RTS (Repair Tractor Station) and other small workshops, it is most difficult to make the drill tube (part 3). Should it be impossible to make a 260 mm tube, its length could be reduced to 160 mm and even to 140 mm, by shortening the coupling rod of the connecting piece by 15 mm. The length of the shaft (part 5) is changed accordingly. Only a 10 cm soil sample can be taken in one operation with a sampler with a shortened tube. The quality of the work does not suffer but it requires more time.

Assembling the Sampler. The handle is inserted and fastened to the head, then the shaft (part 5) is screwed onto the head, the connecting piece is screwed to the shaft and, finally, the tube is attached. The tip is inserted into the tube immediately before sampling. This is the most delicate and volnerable part of the sampler. When not in operation, the assembled sampler should not be pointed with its tip downward so that it will not rest on the ground and, especially, stone or iron. When transporting the sampler without a case, the tube with the tip should be removed to protect it from damage. Since the sampler must frequently be taken during work, all its parts must be kept clean and tightly screwed, but not overtightened.

Sampling. The sampler is operated by two people; one person samples and the other collects the samples. The samples are measured and placed into drying containers or laid out for morphological description. In the latter case, it is most convenient to place the samples into soil boxes. The internal dimensions of individual compartments must measure 11 mm in depth, 12 mm across and 200 mm in length. The soil boxes may be made of various materials such as cardboard, wood or even tin. They can be either small or large boxes with many compartments. Cardboard boxes with five compartments which can hold one meter of core are the most convenient. They may be in the form of a long, narrow box measuring 1060 mm in length and divided into five sections, or of short boxes 22-23 mm long, with five parallel compartments each. Long cardboard boxes are usually fastened to each other to prevent them from turning over. Wooden containers are in the form of grooves in a 12 x 12 mm board. Usually 3-6 such grooves are made in a board of a corresponding length. Shorter boards have either 5 or 10 grooves.

The sampler is driven into the soil by applying pressure and should not be turned while this is being done. If the operator is unable to push the sampler into the soil, it is hammered in lightly with a wooden hammer (iron should not be used for this purpose). The sampler is driven into the soil in one operation to a depth of 10 or 20 cm, but not more than the length of the tube would permit. When the sampler reaches the required depth, it is turned clockwise around its axis to break the sample from the underlying layers and then lifted from the soil. The sampler is then placed in a horizontal position in such a way that the mark indicating the position of the scoop points upward. The

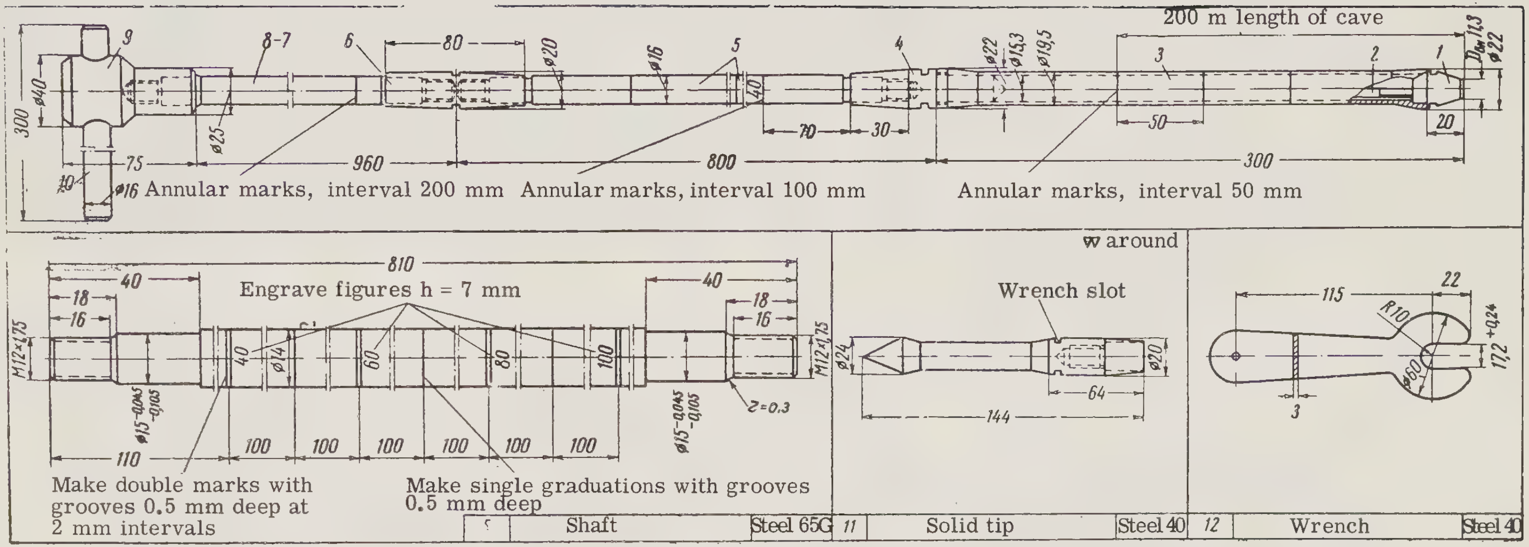

Fig. 2a. - A technical drawing of the small-diameter sampler designed by S.F.Negovelov (for nomenclature of details see the text).

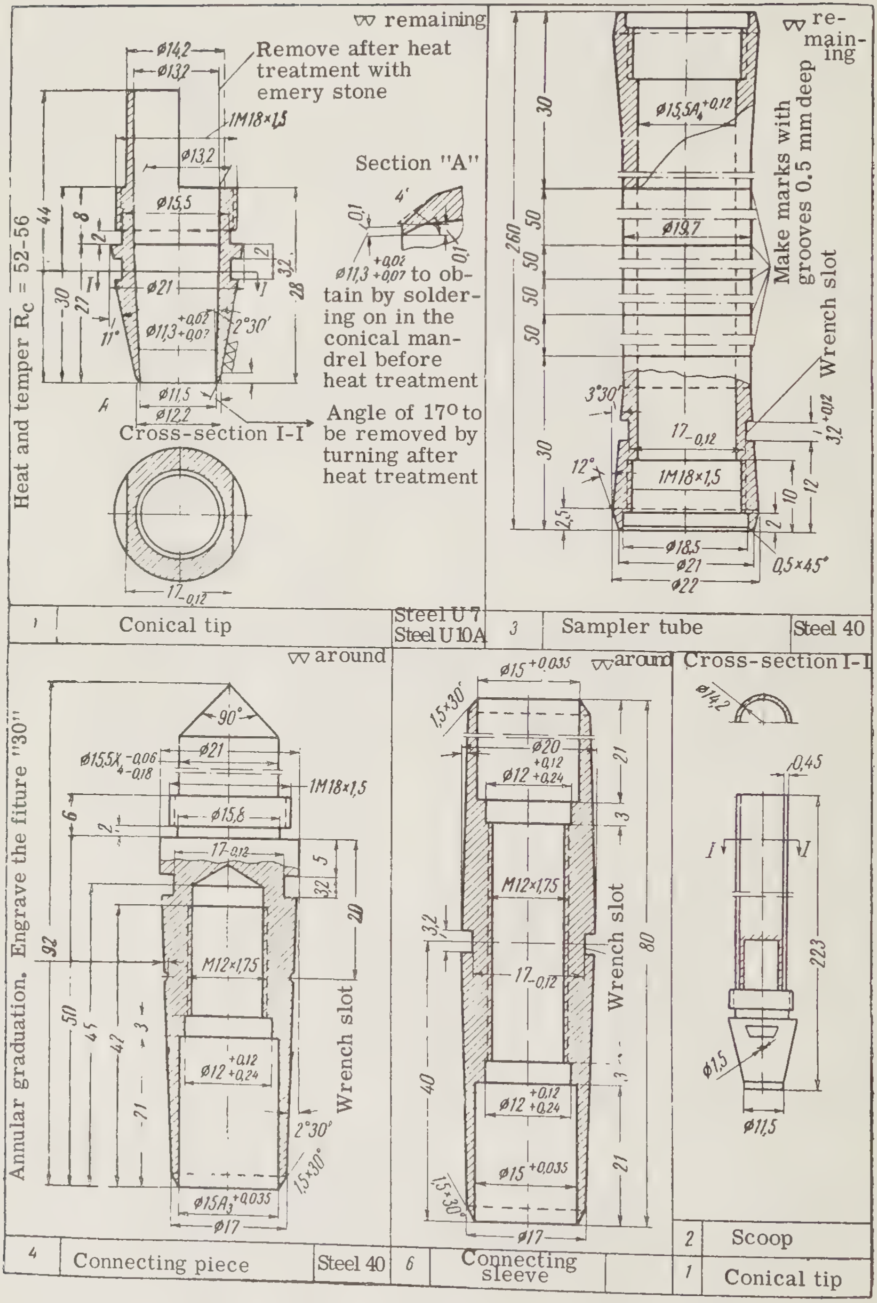
▽▽ remaining
Remove after heat treatment with emery stone
ø14,2
ø13,2
1M18×1,5
Section "A"
ø11,3 +0,02 +0,07 to obtain by soldering on in the conical mandrel before heat treatment
Angle of 17° to be removed by turning after heat treatment
Cross-section I-I
17-0,12
2°30'
Heat and temper Rc = 52-56
1
Conical tip
Steel U 7
Steel U10A
▽▽ re-maining
ø15,5A4 +0,12
ø19,7
Make marks with grooves 0.5 mm deep
Wrench slot
260
3°30'
12°
1M18×1,5
ø18,5
ø21
ø22
0,5×45°
3
Sampler tube
Steel 40
▽▽ around
90°
ø21
ø15,5X4 -0,06 -0,18
ø15,8
M12×1,75
ø12 +0,12 +0,24
ø15A3 +0,035
ø17
Wrench slot
1,5×30°
Annular graduation. Engrave the fiture "30"
4
Connecting piece
Steel 40
ø15 +0,035
▽▽ around
ø20
M12×1,75
17-0,12
Wrench slot
6
Connecting sleeve
Cross-section I-I
ø14,2
0,45
223
ø1,5
ø11,5
2
Scoop
1
Conical tip

Fig. 2b

Table 1

List of parts showing their weight, quality of material and dimensions of dummies

No. of part	Nomenclature	Material (brands of steel)	Quantity	Weight, in kg		Dimensions of dummies, in mm
				Net	Gross	
1	Conical tip	U—7;U—10A	4	0,022	0,150	D 22×45
2	Scoop	Brass	4	0,017	0,018	22×0,45×200
3	Sampler tube	Steel 40	2	0,210	0,960	D24×270
4	Connecting piece	Steel 40	1	0,120	0,300	D22×95
5	Shaft (drilled down to 1 m)	Steel 65G	1	1,270	1,300	D 16×815
6	Connecting sleeve	Steel 40	2	0,146	0,263	D22×83
7	Shaft (drilled down to 2 m)	Steel 65G	1	1,540	1,740	D 16×1000
8	Shaft (drilled down to 3 m)	Steel 65G	1	1,540	1,740	D 16×1000
9	Head	Steel 40	1	0,377	1,06	D45×80
10	Handle	Steel 40	1	0,473	0,480	D16×302
11	Solid tip	Steel 40	1	0,226	0,515	D25×147
12	Wrench	Steel 20	2	0,090	0,250	55×3,5×170

Note: Comma represents decimal point.

rench is used to hold the tip and the tube is uncrewed by turning the whole sampler. When ampling deeper than one meter, the tube with the ip is first removed from the connecting piece and hen the tube is unscrewed from the tip.

Care should be taken that the holes be strictly ertical; this provides for more accurate and easy ork. It is much more difficult to sample holes n a slant, especially if they are deep.

Care of the Sampler during Operation. While ampling moist soil, lubricating grease should e applied to the tip, the tube and the entire urface. If the sampler is lubricated more ften and more thoroughly when the moisture ontent of the soil is high.

Special attention should be paid to the cleanng and lubrication of the tip. The soil which ecomes wedged in angle α of the cutting edge nd strongly adheres to it should be completely emoved. Sometimes this must be done each me a sample is taken because the adhering oil reduces angle α, increases friction, and e soil sample greatly deforms. It is advisble to lubricate the inner surface of the tip nd tube and when wipe them off with a dry oil loth. So little grease is left on the tip and ibe that it cannot affect the content of oranic matter in the soil. While lubrication acilitates sampling and reduces the deformaon of samples, it promotes the slipping of e core from the sampler when the soil is moist.

If the soil is very moist and sticky, a vacuum rms in the hole when the sampler is being fted and the core is sucked out of the sampler. his can be prevented in the following manner; vo 20-25 mm pieces of 3 mm wire are soldered the opposite sides of the end of the tube facg the tip. The ends of the wires are smoothed ith a file. A sampler provided with such a be makes an oval rather than a round hole. it is turned 90° during the removal of the ampler from the soil no vacuum will form. ich a modified sampler can be used for taking samples not only from a saturated soil, but also from below the water table.

When operating a sampler of this kind, strict attention should be paid to the depth of penetration. Too much soil in the tube may break the scoop. Overfilling of the tube may occur because of the carelessness of the operator when the walls of the hole collapse, which frequently occurs in a loose plowed field. To prevent this, it is recommended that the plowed layer of the soil be removed and undisturbed soil be sampled.

The breakage of the scoop does not mean that the sampler can no longer be used. When samples are taken for moisture content determinations, it is recommended that the tube be unscrewed together with the tip and the soil shaken out into a drying container. The same procedure could be followed in other operations, but the results are not as good as when the scoop is used.

The spear-shaped tip (detail 12) is used for sampling to a given depth without taking a sample, for widening deep holes, and for breaking or moving aside stones and recent hard formations encountered while sampling.

It should be pointed out that work with this sampler, as with any instruments, requires a certain experience. Once such experience has been gained, this sampler can be used very effectively by soil scientists.

After 25 years of work with this sampler the author has worked out various methods for its most efficient operation. They include a special method of surveying samples and soils stored in boxes, determining bulk density on a large scale and determining directly the mm of water content. All this, however, cannot be described in sufficient detail in a short magazine article.

Received February 19, 1959

S. F. NEGOVELOV'S SOIL SAMPLER

V. I. POPOV

In our opinion the soil sampler designed by S. F. Negovelov is the most efficient one among various models of soil samplers used in surveying. This sampler has the necessary degree of accuracy, allows fairly rapid sampling to a depth of 1-2 m and deeper, and is comparatively light, simple and easy to operate.

The author worked with this sampler from 1955-1957 in the forest-steppe zone of Belgorod Region. The sampler was tested in all soils found in the forest-steppe zone and gave good results in most of the cases. It proved to be especially suitable for thick leached podzolized chernozem and gray forest soil prevailing in the forest-steppe zone. Good results were also obtained in drilling in solonetz-like and solodized chernozems, solonetzes, meadow-chernozem and other soils. The sampler performed equally well in coarse- and fine-textured soils.

The sampler was used for more accurately determining the boundaries of soil units. The soil sample obtained could be used to determine the main morphological features of the soil (color, consistence, various secretions, new-formations, thickness of genetic horizons, nature of the transition between different horizons, etc.), allowing rapid and accurate determination of the soil group, sub-group or species. This sampler can also be used to take samples to a depth of 3 m for determining the moisture content, and bulk and particle density. One of the advantages of S. F. Negovelov's sampler is its efficiency; sampling to a depth of up to 2 m can be easily done in 20-30 minutes.

In the course of our work we detected certain shortcomings of this sampler. Thus it is more difficult to work with this sampler in loose and dry soils. These soils include, first of all, humus-carbonate, carbonate and slightly calcareous types of thick chernozem. While sampling in such soils, which are loose and slightly dry in the upper part of their A horizon, the tip sometimes became clogged, causing considerable displacement of the soil. It is therefore advisable, when working in such soils, to drive the solid head through the upper part of the A horizon and then start sampling from a depth of 30-40 cm, or remove the upper layer of the soil with a spade. It is also difficult to work with this sampler in wet, saturated soils, since the head becomes clogged more rapidly than in dry soils.[1]

Conclusions

1. The sampler of S. F. Negovelov is the best of the samples used in soil mapping.

2. When used in the forest-steppe zone, the sampler can be of much help to soil scientists engaged in the determination of the soil boundaries.

3. It would be desirable to mass produce the soil sampler designed by S. F. Negovelov.

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[1] The S. F. Negovelov sampler is not suitable for work in coarse textured soils containing stones, recent inclusions of carbonates (Zhuravchiks), etc., since it wears out and breaks easily (Editor's note).

REVIEW

FOREST SOILS, THEIR PROPERTIES AND RELATION TO SILVICULTURE, S.A. Wilde, The Ronald Press Co., N.Y. 1958, pp. 537.

Reviewed by N. P. REMEZOV and R. M. ALEKSAKHIN

Forests occupy a vast portion of the earth's surface. Many soils now used for crops, meadows, and orchards had in the past been ong exposed to the influence of forest vegetation as revealed by their present structural properties. That is why investigation of forest soils is exceptionally important for a sound knowledge of the soil in general. Research on he structural and cultural properties of these soils is urgent owing to the growing need of wood and diminishing reserves throughout the world.[1]

Thus publication of the second edition of Professor S. A. Wilde's Forest Soils is an important event. This University of Wisconsin professor is known for his research in forest soil science. The first edition of his monograph appeared in 1942 and was reviewed by Yu. A. Liverovskiy in Pochvovedeniye, No. 5-6, 1945. This review will critically analyze Wilde's soil classification system and not the book as a whole.

The new 1958 edition has been substantially enlarged in many sections and can be considered n independent work. The foreword states that he book has been written both for students and pecialists in the use of forest land.

The first and largest part of the work (320 ut of 496 pages of text) is called "The Soil as Medium for the Growth of Trees" and describes the general properties of the soil: mineralogical composition, organic matter, adsorption capacity, reaction, etc. It begins with a survey of silvicultural research from ncient times to the present. The survey contains a considerable amount of interesting information, some of it debatable. For example, Wilde writes that the earliest information relating to the effect of the soil on forests was btained many centuries ago in Eurasia by the Mongol tribesmen, but he fails to mention the art played by the Slavs. He overlooks the act that the Mongols as inhabitants of the steppe ad less contact with forests than the Slavs. nd he fails to utilize fully the materials of Russian forest soil research, as evidenced by the few references to the extensive work of the past 20 to 30 years. The value of the monograph is thus reduced because the Soviets have made a major contribution to the field.

Wilde defines forest soils as "portions of the earth's surface serving to nourish forest vegetation; it (the surface - N.R.) consists of minerals and organic matter combined with varying amounts of water and air and inhabited by organisms; it acquires special properties due to the factors of soil formation not characteristic of other soils: forest litter, tree roots, and certain organisms whose existence depends on forest vegetation" (p. 9).

Chapter 2 contains fairly complete information on the minerals in the soil, genesis and characteristics, main parent material.

Chapter 3 "Organisms in Forest Soils" is exceptionally useful. It describes in detail the root systems of various species of trees and their structure, the bacteria, fungi, actinomycetes, algae, protozoa, worms, insects, mammals, and other inhabitants of the soil. The reader will find here interesting data concerning the scale on which plant and animal residues are worked over by the microflora and fauna of forest litter and soil. For example, Crompton says that beetles in England and Wales destroy about 200 billion insects every year weighing more than the population of the British isles. Nevertheless, the treatment of organisms is far from complete. Describing the activity of the nitrogen-fixing microorganisms, the author does not mention the oligonitrophils which are very common in forest soils. The activity of earth worms could be treated in a more detailed manner.

A great deal of attention is paid to the humus of forest soils in chapter 4. Wilde goes back to the classical investigations of Emeis (1875) and Mueller (1879, 1884) for his division of humus into mull and mor with a further detailed breakdown into finer units. Wilde relates the various kinds of accumulation of dead organic matter to the conditions favoring the production of the following three forms: (1) ectohumus, consisting of nondecomposed or incompletely decomposed plant residues on the surface of the soil; (2) endohumus, represented by finely dispersed organic matter washed into the soil and closely interacting with the soil minerals; (3) cryptohumus, consisting of light-colored (pale yellow) organic compounds.

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[1] Heske. Groesse und Verteilung der Waelder der rde. Z. Weltforstwirtsch., 1955, 18, No. 5-6, p. 165-181.

Following the Scandinavian investigators, Wilde distinguishes three layers of ectohumus: litter (L), fermentation layer (F-layer), and humus-formation layer (H-layer). Ectohumus apparently corresponds to coarse humus or mor (according to the older investigators) while endohumus corresponds to soft humus or mull. It must be admitted that the identification of a special kind of light-colored humus abundant in tropical and subtropical soils is useful, although the name - cryptohumus - is not very apt.

Wilde distinguishes two main groups of humus layers in relation to the climatic conditions and nature of the original material influencing the rate and course of decomposition of dead plant and animal residues: megoorganic and oligoorganic. The former is formed when plant residues are slow to disintegrate or they are added to the soil faster than they can disintegrate, e. g., rich mull and heavy mor. The latter is formed when the litter decomposes too rapidly or too little is available, e. g., velum (from the Latin word for "veil"). The author points out that "velum" was first suggested by G. N. Vysotskiy to designate forest litter. This humus is poor in nitrogen and is formed when the litter is meager. Wilde includes cryptohumus among the oligoorganic layers. It has considerable nitrogen, lean sward, lean mor, and hydrosolic melazones, the latter characterized as dark patches formed by humic substances with low nitrogen content. On the last few pages of the chapter Wilde briefly describes the commonest types of humus layers in forest soils using the conventional United States system of classification. He mentions the genesis and morphological structure of each type as well as the major characteristics.

Wilde concedes that the principle of classifying the forms in which dead organic matter is produced and accumulated in forest soils solely on the basis of morphological structure "cannot be accepted without qualifications and limitations" (p. 86), for "the genetic development of forest soils is primarily the result of biological activity and complex biochemical transformations visibly reflected in the external appearance and structure of the layers of humus" (p. 99).

In an effort to fill this gap, Wilde devotes a special section to the chemical and microbiological properties of various kinds of forest humus. The contents of this section reveal inadequate study of the chemical composition of the various kinds of forest humus. Of greatest interest are the experiments to determine the effect of forest humus on the growth of spruce seedlings and the effect of volatile substances of organic substances released by humus on the growth of lupine roots (pp. 90 and 93). The author concludes with a discussion of the silvicultural significance of the forms of humus and their influence on soil formation. Like many other investigators of forest soils, Wilde fails to make a rigorous distinction between humus proper and nonhumified plant residues, as is clearly evident in his treatment of ectohumus. This widened use of the term "humus" is unsound.

Chapter 5 deals with the genesis of forest soils. Although he repeatedly mentions the importance of forest vegetation in soil formation, Wilde assigns the major role to the climate and geological structure of the locality. "Great though the influence of forest vegetation may be (on the process of soil formation - ed.)," he says, "it cannot be compared with the more powerful action of the climate, topography, and parent material" (p. 118). Wilde does not mention any of the Soviet soil scientists who have studied this problem.

A short section entitled "Biotic Factors in Soil Formation" describes in only the most general terms the effect of forests on the soil. It should have been enlarged to include experimental data.

Wilde's remarks on the process of soil formation are interesting not only as a reflection of his personal views, but also as a means of familiarizing us with current thinking in the United States in the field of soil genesis.

The author distinguishes three types of weathering: a) physical; b) sialization, occurring in areas with a temperate climate; and c) feralization, characteristic of tropical and subtropical areas. As forest vegetation becomes established and the litter turns into humus, the weathering processes come under the influence of the soil-forming processes which include, according to Wilde: a) leucinization, or the biochemical process of destroying the black pigments of organic matter; b) melanization, or the process of forming endoorganic humus of the mull type, increasing the content of exchangeable cations and nutrients, and promoting stable fertility; c) podzol formation; and d) gley formation.

In describing the structure of the soil profiles Wilde divides them into genetic horizons following the letter symbols used in the USSR.

Chapters 6 and 7 deal with the classification of forest soils. They are divided into two large groups: soils of plains and mountains, where the upper end of the capillary border of the ground water does not reach the roots of the various trees (chapter 6), and hydromorphic soils (chapter 7). The influence of P. S. Kossovich, S. S. Neustruyev, and S. A. Zakharov is manifest in this division.

Wilde's first group includes the following soils: a) embryonic (primitive); b) cryptoorganic - these are mainly the soils of tropical forests, characterized by rapid mineralization of the litter; c) melanized, characterized by the formation of a black layer of humus 10-60 cm thick and found in areas with various climates; d) podzolic, ranging from the thick taiga podzols of the tropical areas, all characterized by the presence of a podzolic horizon poor in sesquioxides.

Hydromorphic soils also have several subgroups: a) gleyed; b) vadose, in which gleying starts from the surface under the influence of atmospheric precipitation; and c) organic, characterized by the formation of a layer of peat.

The author uses rich factual material for further subdivision of the soil, which we are unable to examine in detail in this review. The description of tropical soils, scarcely known to Soviet soil scientists until recently, is exceptionally useful. Of value too is the account of the species of trees growing on each of the soils discussed.

A shortcoming of the book is the author's clinging to the obsolete hypothesis of S. I. Korzhinskiy on the degradation of steppe soils following the growth of broadleaf trees. The hypothesis was not confirmed by recent Soviet research. In his review of the first edition of the book Yu. A. Liverovskiy referred to the fact that Wilde had abandoned genetic principles in connection with soil classification.

Chapters 8 and 9 contain a brief, but interesting description of the main chemical and physical properties of forest soils. Despite their brevity, these chapters throw light on a number of modern problems in soil science: the role of trace elements in the physiology of trees (chiefly fruit trees), the effect of chelates on the availability of nutrients to plants, migration of these elements in the soil, etc.

The attempt to discover the point at which trees feel the deficiency of physiologically available compounds of nitrogen, phosphorus, potassium, calcium, and boron is very interesting. Unfortunately, the author does not always state the methods used to determine these elements on the basis of which he reached his conclusions. The physical properties of the soils are described more simply.

It is perplexing to find the out-of-date diagram (based on 19th century data) of the bioogical cycle of elements under pine and beech p. 219) borrowed from Dengler's textbook 1930). Here too the author shows his unamiliarity with the work done in the USSR in his field during the past twenty years.

Chapter 10 on the "Relation of Forest Vegeation to Soil Conditions" illustrates the breadth and completeness of the author's factual materil. His description of forest massifs in various parts of the world (North America, Europe, and Manchuria) highlights the close interrelationhip existing between forest vegetation and ocal soil conditions. The data are of coniderable comparative geographic interest. Tropical and subtropical forests were not disussed in this connection, apparently because f the lack of pertinent materials. A serious hortcoming is the author's adherence to Clements' erroneous conception of the so-called climax association," the untenability of which as long since been demonstrated in Soviet iterature.

The diagram of soil distribution by toporaphy in the Black Forest of the Ukraine (p. 81), on which podzolic soils are shown in low elief, is questionable.

The second and smaller portion of the book 175 pages) entitled "Soil Science and Silviulture" examines the properties of soil in conection with the principal management practices, forest soil scientists and foresters will find much valuable practical material here.

Chapter 11 is particularly interesting for its account of the problems involved in growing seedlings in forest nurseries. It comprises the general principles to be followed in setting up nurseries, soil conditions required, details on the use of mineral fertilizers, compost, and green manure. A special section is devoted to the use of liquid humate fertilizers (pp. 350-352).

Chapter 12 examines methods of controlling soil fertility in forest nurseries and describes ways of providing seedlings with nutrients and moisture, eliminating unfavorable soil properties, evaluating the seedlings raised, etc.

Information on the control of insect pests and weeds in forest nurseries, including the latest chemical techniques, is presented in chapter 13.

Chapter 14 on mapping and evaluating soils for silvicultural and timber purposes is less successful. The treatment is too schematic and the proposals for soil nomenclature are highly debatable. The author departs from the principles of Dokuchayev genetic soil science without good reason.

The following chapters on afforestation (chapter 15) and improvement of unproductive soils (chapter 16) are much better and provide an abundance of valuable information.

Chapter 17 on "Soils and Forest Management Cutting" includes an interesting diagram (p. 461) for studying the effect of various management practices on the soil. The following pages contain recommendations for continuous cutting, regeneration cutting, and care in the temperate zone. Consultation of the pertinent Soviet literature would have supplied the author with factual material for a more profound discussion of the effect of cutting on the properties of the soil. There is no reference to the effect of forest fires on the soil.

The economics of forest management is discussed in chapter 18, the last chapter. It was written with reference to the capitalist system and therefore has only academic interest for the Soviet reader.

The book has numerous diagrams and photographs that are very helpful in understanding the text. The interesting epigraphs selected for the individual chapters are noteworthy. There are numerous references to a variety of published materials thus testifying to the author's high cultural level.

To sum up, Wilde has produced an extremely valuable manual on forest soil science both for specialists on forest soils and for soil scientists, foresters, botanists, and geographers in general. One cannot agree with all of his views since they reflect many notions prevalent in the United States and unacceptable to Soviet scientists. At the same time, it is worth noting that he shows the influence of the most important older Russian soil scientists, particularly Vysotskiy. We have already pointed out that Wilde has almost completely ignored Soviet publications over the past 20 to 30 years and thus detracted from the value of his book.

Since we still have no monograph in Russian on forest soils and forest soil science, it would be exceptionally worthwhile to have a Russian translation of the work along with appropriate notes and an introduction. A wide group of readers would find it interesting and useful.

CHRONICLE

NIKOLAY VASIL'YEVICH ORLOVSKIY

The 60th Anniversary and 35 years of Scientific-Agronomical and Social Activity

Colleagues and students

February 1959 marked the 60th birthday and
5th anniversary of the scientific and public
areer of Professor Nikolay Vasil'yevich Or-
ovskiy, Doctor of Agricultural Sciences.

While still a student in the Timiryazev
gricultural Academy in 1921-1922 Orlovskiy
onducted a series of experiments with mineral
ertilizers on the reclaimed bogs near Moscow
nd in the sovkhozes of the Glavsemkhoz. He
lid his graduate work in the laboratory of D.
N. Pryanishnikov. After graduation from the
cademy in 1924-1925, he worked in the
Buzulukskaya Experimental Station under the
irection of the well-known experimental
cientist S.S. Bazhanov. In 1926-1927 he
eaded the seed-growing section of the Saratov
Oblast' Agricultural Administration and in the
Lower Volga region organized seed growing
nder the direction of Prof. G.K. Meyster. In
927 he set up an agricultural chemical labora-
ory at the Ural Experimental Station (Western
Kazakhstan). From that time on he has been
ontinuously engaged in experimental work: in
Western Kazakhstan until 1933, then in Siberia
Siberian Agricultural Research Institute, Si-
erian Research Institute of Animal Husbandry
nd Ubinsk Experimental Station for Meliora-
ion, experimental stations and zonal institutes
n Altay and Krasnoyarsk krays). He began to
each in 1944, first in Novosibirsk (1944-1950),
hen in Altay (1950-1958), and finally in Krasno-
arsk Agricultural Institute where he is present-
y chairman of the Department of Soil Science
nd Agricultural Chemistry.

Orlovskiy is the author of more than 60
ublications. He has studied important prob-
ems of immediate significance in the field of
griculture, e.g., agromonic appraisal of
atural fallow lands and rotation of crops with
erennial grasses in Western Kazakhstan. In
ddition to analyzing soil formation in the low-
ands, characteristic of Western Kazakhstan
nd the Transvolga region, he has investigated
he manifold influence of irrigation on the col-
oidal complex, physical properties, nutrient
nd salt relations of chestnut solonetz soils.

His work on saline soils is widely known.
e was the first to experiment with gypsum on
e irrigated solonetz soils of Western Kazakh-
tan. These experiments were continued in
msk Oblast' (1934-1938) on nonirrigated soils.
e devised a method of filling patches of solonetzes with chernozem soil. The method is now being used in actual practice.

He has conducted extensive research on the action of mineral fertilizers on soils of the chernozem-solonetz complex, particularly on the toxic effect of adsorbed sodium and salts on crops, ending in a classification of crops by degree of salt tolerance to suit the conditions of Baraba. In recent years (1953-1958) he directed efforts in the sovkhozes of Altay kray to devise methods of cultivating solonetzes for forage crop rotations, including sweet clover and perennial grasses. The methods involved deep plowing without turning over the columnar solonetz horizon. The demonstrated effectiveness of gypsum in arid Kulunda in these crop rotations make it possible to exploit the rich deposits of lake gypsum.

While supervising the program of the Ubinsk Experimental Station for Melioration (1938-1950) Orlovskiy trained a competent group of scientists and established the basic principles to be followed in reclaiming the saline bogs of Baraba. Kolkhozes and sovkhozes in Novosibirsk and Omsk Oblasts are using his system to drain local bogs.

The research conducted between 1951 and 1957 focussed on the soil meliorative conditions of the Aley irrigation system of Altay kray, water and salt relations of the soil, causes of secondary salinization and measures to control the process and improve the meliorative condition of the system.

Orlovskiy's book Development of Virgin and Abandoned Lands in Altay Province (1955) gives a detailed description of old and new, practical and scientific experience. He has actively participated in the efforts to devise procedures for developing new lands and to classify the soils in these regions for production purposes. A field team has already begun work on a description of the characteristics of Altay kray soils suitable for cultivation.

Orlovskiy's lectures are comprehensive and filled with facts. Many of his co-workers have defended their dissertations and are now working in the schools and experimental organizations of Siberia and Kazakhstan. Orlovskiy has been active in major phases of agriculture: organization of sovkhozes, use of chemicals for various purposes, shelterbelts, development of virgin lands, systems of managing farms, etc. His addresses are marked by deep devotion to principle and sincere concern for the success of the measure in question. They are highly stimulating to his scientific colleagues.

Orlovskiy has worked, frequently as a pioneer, in the difficult conditions existing in the eastern regions of Western Kazakhstan, Western Siberia, and Altay. Through his indomitable energy, love of work and the science of agriculture he has organized a group of competent, friendly, and resolute workers.

The many friends and students of Orlovskiy wish him good health and new achievements in advancing soil science and in training agronomists for service in Siberia.

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